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## A new science curriculum : a study of pupils and teachers' perceptions of gender and science education, from a feminist, reflective practitioner's perspective

### Thesis

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Doctor of Education (EdD)

A New Science Curriculum: a study of pupils and teachers' perceptions of gender and science education, from a feminist, reflective practitioner's perspective.

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RO 276463

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## ABSTRACT

Concerns about the low representation of women in science and technology have been voiced for many years by scientists and non-scientists alike and have been the subject of much debate and research in education by governments and individuals. Current concerns about the under-achievement of boys have led to the specific issue in secondary education of girls and physics sliding down the political agenda but the continuing general decline in the numbers of pupils opting for science is a worrying trend which needs to be addressed.

Women's studies have involved looking for alternative approaches to the male dominated and orientated scientific establishment and feminist writers have discussed this area of discrimination and inequality from different standpoints. In this research, I used a feminist approach which emphasises: improving women's lives; criticising dominant systems of knowledge; being praxis-orientated and creative in order to change the way physics is taught in school.

I carried out the research through the use of semi-structured interviews with pupils and teachers to shed light on the research questions which asked why boys felt encouraged to study physics whilst girls opted for other subjects; how teachers perceived science and how a feminist perspective could be related to a new science curriculum.

The outcomes from interviews with pupils and teachers suggested ways in which physics could be more gender inclusive, by adopting interdisciplinary approaches, greater cross-curricular work and moving away from the emphasis on scientific facts towards greater debate and discussion. Further interviews with focus groups and case studies teachers pointed to possible changes and successful alternatives for physics classes through the adoption of different approaches: changing not only what was taught but how it was taught.

I then worked with curriculum development colleagues to create a new science curriculum and this was successfully implemented in classes, showing that a change in approach to teaching about physics at school level is essential and could lead to greater pupil engagement in physics classes.

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I am also indebted to Angela Srivastava, my tutor, who was a wonderful support and motivator and helped to keep my interest in the work through her consistently encouraging comments and suggestions.

The curriculum development teachers' contribution was invaluable through their passion for science, knowledge of their pupils and yearning for a new approach to science teaching.

Finally, I am tremendously appreciative of the teachers and pupils who so generously shared their ideas and perceptions of science education. They willingly spent time and energy to help me in this research and their enthusiasm for change was inspiring.

My hope is that this research will contribute towards improving science education for all our learners.

# **CHAPTER 1: CONTEXT OF THE RESEARCH**

## **Introduction**

This thesis presents an account of reflexive research into pupils' and teachers' attitudes towards the science which is taught in secondary schools and tests some alternative approaches to teaching science based on feminist informed perspectives.

The issue of women and science has perplexed scientists and non-scientists alike for many years with continuing concern for the low representation of women in science, particularly the physical sciences. The scarcity of women in science is a concern because of the power which science and technology has in our society: exclusion from science equates with exclusion from power. It also excludes women from contributing to the development of a new science and technologies.

The study looks at the perceptions which pupils and teachers have towards science and the issues which lead to many girls opting for courses other than the physical sciences. It also addresses the question of whether feminist studies on science and science education can in practice offer alternative ways of making science more inclusive. As such, it is a reflective practitioner project using a feminist approach as the main theoretical basis of the research.

The research process has been an iterative one, developing from my experience as a teacher of chemistry and physics over the last twenty years and moving from a position of trying to encourage more girls into these subject areas towards questioning the science which is taught with a view to changing it. Reflecting on my own role in teaching in this field, it was a continual preoccupation that in spite of many schemes to encourage more girls into physics, the situation had not really altered since I was a pupil and girls remained in the minority in these classes at higher levels of secondary education.

As a woman working in the field of science, it was initially difficult to understand the reasons for the low participation of girls in physics classes when there appeared to me to be no issues of access in terms of being able

to choose to study this subject and when levels of achievement between girls and boys were similar in science at lower school levels.

Throughout my own pupil days then as a teacher of science from the 1980s, I worked within the system and accepted the status quo. There seemed to me to be no obvious signs of discrimination against the girls or bias towards the boys and from my perspective at that time, all that perhaps was needed was to give girls more encouragement to succeed at higher levels. However, various initiatives designed to encourage more girls into physics met with limited success.

My interest in studies on gender and education led to further reading of feminist writers on science and science education. This literature put forward the idea that instead of seeing the problem as lying with the girls, perhaps it was science itself which needed to change. Feminist literature has critically analysed science and the scientific establishment and this has often shown that it is shaped by masculine values and is male biased. Women's studies offer an alternative approach to looking at the science which is taught and questioning its biases through an analysis which begins with women's lives.

Feminist writers, such as Miles and Middleton (1995) argue that the gender bias in contemporary science is perpetuated through cultural influences:

*“the values and procedures of Western science tend to be gender-specific, reflecting distinctly masculine modes of thought and understanding ... these differences are social and historical in origin, not innate”*

*(Miles and Middleton, 1995, p. 135).*

This offered a different perspective to the subject I was teaching, as I had never before questioned the science I taught or the way the curriculum and approach to teaching science had developed. Reading feminist writing helped me to make this conceptual journey, based on the perception that the problem of low participation by women in science is an issue which emanates from women themselves towards a more critical analysis of science and science education.

Feminist writing contains a wide range of different perspectives and approaches to research with the overall intention of improving women's lives. Since this research topic is one concerning gender and education, it seemed appropriate to use the main tenets of feminist epistemology to investigate the reasons behind the scarcity of women in the field of science.

Moreover, the issue of women and science is one which has been debated and commented on from different viewpoints. Various scientific bodies have voiced their concerns over the statistics which show how the already small numbers of women working in science continue to drop as women leave the field to work in other areas (ETAN Report, 2000; Rees, 2001). The reasons given for this trend cover a variety of issues, from lack of role models and scarcity of data on gender statistics to the stereotyping of science as a male sphere of influence.

This study brings together these strands in my position as a reflective practitioner working in science education informed by feminist values and seeking an alternative path to the current position. The research is timely and can make a significant contribution due to changes in policy in the context of the Scottish education system where the curriculum structure and content are currently in the process of reform.

## Policy

The introduction of “A Curriculum for Excellence” (ACfE) in Scotland offers a unique and valuable opportunity to change the experience of education including that of science for all pupils. It opens the way to challenging the current ethos and system of teaching which has been in place for many decades in order to extend the model of the curriculum. Currently still in the development stage (August 2008), ACfE is expected to be delivered by all schools and centres across Scotland from 2009-2010. The strategy employed sets out to adopt a range of experiences which promote effective learning and to widen the definition of what and how children learn. It proposes a smooth transition within teaching and learning for pupils throughout their school years from ages 3-18 through an overarching curriculum which has the intention of creating a challenging and interesting programme for all pupils.

ACfE has a commitment to “declutter” the curriculum and improve assessment loading, with:

*“curriculum areas and subjects revised and enriched through the review process to provide challenge and enjoyment, depth and relevance” (ACfE, 2006, p.20).*

The new policy suggests that there will be more flexibility within the system for an exploration of key concepts through greater use of a cross-curricular approach with the ultimate goal of increasing pupils’ understanding of the real world and engaging pupils in a more inclusive curriculum. To this extent, ACfE and the research I have carried out are moving towards similar goals. However, it is striking that at this stage of development, no mention is made of gender in ACfE in contrast to my research which specifically underlines the need for gender issues to be highlighted in changes to the science curriculum in order to develop more inclusive practice.

The Scottish Executive has invited contributions from various scientific bodies as well as teaching staff, pupils and outside agencies with a view to creating a new curriculum which allows more negotiation of the learning process. This is interesting from the point of view of my research, as the

work I have carried out in terms of developing a new science curriculum makes a significant contribution to this new policy.

Success for the new curriculum depends on teachers to take up the challenge, question the science as it is currently taught and implement changes in their approaches to teaching science. This depends on the support they are given in working with this wider remit as well as a commitment by teachers to significantly reform science education, and it is this contribution to change which is offered by the research I have carried out.



## **Why Focus on Science Education?**

Science education is important because it begins the process of entrance into the field of science and technology. Science, technology and the resulting industry have become associated with power in our society and the ETAN Report (2000) specifically outlines the link between European wealth and science. However, it also notes that those who are excluded from this field, predominantly women, are prevented from contributing to policy, the decision making process of the scientific establishment and the development of new science and technologies.

Statistics show a marked decline in general in the numbers of pupils taking university entrance level examinations in science over the years. Barmby and Defty (2006) note that the numbers of pupils opting for Advanced level physics has declined by 38% in England and Wales in the last twenty years, whilst in Scotland the picture is similar with a 30% reduction in the number of entrants for Higher level physics from 1987-2006 (Scottish Qualifications Authority). Thus, the statistics point to a need to address the problem of the declining popularity of science for all pupils. These figures have resulted in well-publicised cases of university chemistry and physics departments closing and point to a need to explore the reasons for this decline and why pupils are opting for other subjects in the curriculum. When analysed by gender, the statistics show that of the total numbers of entrants in both Scotland and England and Wales only some 20-30% of candidates for physics examinations are girls.

The research questions arose from my observations as a practitioner in the field and the figures showing that very few girls were opting to study physics beyond compulsory or post-16 level. In teaching physics at secondary school level it was apparent to me that as soon as the pupils had the option to continue a subject for further study or leave it for alternative choices, few girls remained in advanced level physics classes. However, many of the teachers I had worked with had not seen this as a problem which required attention, as Zohar and Bronshtein (2005) note elsewhere.

Although there have been many initiatives and programmes to encourage more girls into this field, such as the Women into Science, Technology and

Construction programme (Weiner, 1994), these have not been as successful as had been hoped, as statistics indicate a continuing fall in the numbers of women in the physical sciences. Technology is based on science and it is this which propels industry and therefore power in society. If women are excluded from this area, then they are not involved in the areas of life where power is wielded (Haraway, 1991) and are thus removed from many important decision making processes at a wider level.

The question of why girls are opting for other subjects goes beyond issues of opportunity and access to science courses, since in principle all pupils can choose to follow their preferred course. The problem also goes beyond questions of achievement since many pupils who choose not to study physical sciences have shown success in this area at lower academic levels.

Figures from the 2007 A level results in physics show that only 22% of entrants were girls, though 34% of girls achieved the top A grade compared to 27% of boys (source: AQA). In Scotland, a similar picture from the 2007 examinations emerges which shows that girls formed 22% of Higher grade entrants and of these 31% of girls, compared with 25% of boys, received grade 1 (the highest grade) (source: SQA). This shows that the girls who do opt for physics are achieving higher grades than the boys proving that reluctance to continue in this subject is not due to ability in this area. It appears that only the more able girls are choosing physics, and this will be discussed later in the study.

My own experience within the teaching profession has been that the boys who have opted to follow a course involving the physical sciences have not necessarily performed better than girls in this area. Some who have struggled to keep up with the work have been determined to follow a physical science course, even though they may show more aptitude for humanities subjects. My research questions then relate to why so few girls continue with physical science in spite of doing well in this area, as well as why some boys persevere with it in spite of finding the subject difficult.

In addition, it seemed that instead of looking to see how girls could be encouraged to join a system which had made them feel unwelcome and lacking, I should also address the issue of just how science teaching could

change in order to make it a better, more inclusive experience for all pupils. The type of approach which I felt was appropriate to this type of investigation involving issues of gender, as grounded in my own experience and based on science practice, was a feminist approach to research (Weiner, 1994). As a feminist, reflective practitioner, I consider it important that norms are challenged, continually revised and reflected upon in order to improve and enrich people's lives.

The research I embarked upon is one which employs reflexivity to question practices and challenges assumptions on which the science education system is based and engages with the main tenets of post-modern feminist research. A feminist praxis (Stanley, 1990) uses both feminist epistemology and research to take action to change unjust practices. In the case of this thesis, my aim was not only to investigate this area of concern but also to bring about an improvement in science education, the premise being that it is not enough to merely research a topic, but that the outcomes should lead to action. The research questions then arose out of the three main themes outlined above and ask:

- 1. What are the mechanisms which both inhibit girls from choosing physics and encourage boys to pursue this subject at post-compulsory level?*
- 2. How do teachers perceive and relate science as a subject in the curriculum?*
- 3. How could a feminist perspective contribute towards a new science curriculum in order to change the approach to teaching physics?*

## **The Context of the Research**

The research is situated in the context of a feminist approach to research. Although there are several feminist methodologies, there are common features which include studying gender relations, a critical analysis of science to show that it is not value free, as it claims, and the adoption of non-hierarchical relationships between researcher and participant, such as through the use of semi-structured interviews and focus groups.

Feminist research is predominantly, though not exclusively, of a qualitative nature and the approach favoured by feminist researchers has often been one that involves semi-structured interviews in order to explore an area, since discussion provides a rich source of data. In the case of this research, I wanted to find out more about how learners and educators viewed science in order to make a contribution to science education policy and practice. It was important that I spoke with both teachers and pupils, since these are the key providers and receivers of the curriculum - so that I could get a better understanding of the issues behind the statistics.

The research questions inform the way the research will be carried out and analysed. They also point to the most appropriate methods for collecting data. Punch (1998) states that this matching between research questions and methods should be as close as possible, with the methods chosen following on from the research questions. The research questions ask “what” and “how” in terms of pupil’s and teacher’s perceptions. The study is centred on science pupils’ experiences and practitioners’ unique and common perspectives and therefore points to qualitative approaches.

The type of questions do not imply the need for numerical data, although it is useful to refer to national examination statistics by gender to illustrate why the issue of girls and physics is of crucial importance to science education policy and practice. In order to find answers to these questions, I needed to talk with the people involved and explore with them their views and observations on the subject.

The research began when I was teaching in Spain, and the pilot work was carried out in a British school in Valencia. The school taught the National Curriculum (England and Wales) in English, and all of the teachers and

most of the pupils interviewed had British origins. The purpose of the pilot work was to give me the opportunity to test out interviewing skills and to refine the types of questions posed to pupils and teachers in order to help shed light on the research questions. Through a group interview with eight girls, then individual interviews with four teachers (two science and two humanities) and eleven pupils (5 humanities and six science), I explored perceptions of science education with practitioners and learners.

The original aim of the research had been to consider the issue of girls and physics through a study of pupils' perceptions of secondary school science and to include some interviews with a few teachers who could give some background to the context. However, the involvement of teachers in the pilot work enhanced the research through providing a wider and richer source of data and I felt that greater input from teachers would help to find answers to the research questions. This led to changes to the main research as a result of the contribution from the pilot work. This will be discussed in greater detail in the third chapter on methodology.

The main research involved interviews with twenty teachers, of whom eleven taught science subjects and nine were humanities teachers. I also interviewed twenty pupils, eleven who had chosen to focus on science subjects and nine who had opted for the humanities. Through discussion in these interviews, I identified key curriculum changes then developed a new curriculum with colleagues, which was then implemented in some science classes to try to create a more inclusive science curriculum.

My personal interest in the area of research began from a background of teaching physics and chemistry, not only in European countries but also in developing countries of the Pacific and Caribbean regions. Throughout my teaching experience, I found that the science syllabuses followed similar subject matter having the same range of topics with little regard to local or national beliefs or customs.

The standard examination taken at the age of 16 in the Caribbean was developed from and accredited by the Cambridge Examination Board following a similar content based science syllabus. Likewise, in the Pacific

Islands, children were presented for the New Zealand School Certificate which was based to a large extent on the Scottish Ordinary grade.

Hence, the science which I have taught in different regions of the world has been one of similar topics, experiments, themes and conclusions. Pupils often followed a 'recipe book' type experiment where they followed instructions, collected data and reached conclusions in a tightly prescribed manner. The teacher was seen as the expert who had the answers to the 'questions' posed by science and who had an understanding of this body of knowledge which was used to explain the world around us.

Throughout a twenty year science teaching career, my experience of teaching about science has been one in which I have seen repeated patterns of pupils, both girls and boys, who worked well in the sciences at compulsory level (up to age 16) then found that physics classes at post-16 level were dominated by the boys. It was this puzzle that I wanted to explore further in order to find answers to why this continued to happen and how alternatives might be found to this unremitting problem.

### **Use of Terms**

This thesis is more concerned with physical rather than biological science since the scarcity of women in science tends to be in the realm of physics. Although the study focuses on the low participation rates of girls in the specific subject of physics, it refers at times to the general term of science, as science subjects tend to be grouped together in the early secondary school years (for pupils aged 12-14) and taught as part of an integrated science programme. The approach to teaching in biology compared to physics can be quite distinctive, and this will be discussed later in the thesis.

Questions which involve gender have undergone scrutiny from feminists in challenging the concept of such binary terms as: "boys" and "girls", where there is a tendency to see these as universal, unchanging categories. Feminist theories find the notion of a fixed self problematic and instead embrace the concept of diversity in gender and identity. However, these tensions which arise in the debate on relativism and realism make this a

difficult path to tread, since, in trying to improve the choices for girls, there is an implicit acceptance of the existence of such a category. However, in this thesis, both terms are used since without them, injustices would not be highlighted. Nevertheless, the intention of the research is to improve the experiences of all our learners through finding out more about pupils and teachers' perceptions of science and addressing gender issues in physics classes.

## **Reflective Practice**

As the title states, this study is concerned with an analysis of pupils' and teachers' attitudes from my perspective as a reflective, feminist practitioner. It would be useful to define these terms at the outset as their meanings can be interpreted in different ways. The three terms are also useful in pointing to the way in which this study makes an original contribution to the body of knowledge on gender and education.

Firstly, teachers have a unique role to play in working with their pupils to create interesting and informative lessons and promote lifelong learning. They also need to develop an understanding of their own practices through reflection on their aims, attitudes and approaches in the classroom, as advocated by Schon (1983). The research I have carried out demonstrates the way in which I have worked with pupils and colleagues to develop an alternative approach to teaching science. This was done through a consideration of the science which has been taught, then an exploration of different ways forward to engage all pupils in the subject and question 'science as usual'.

As a practitioner in the teaching profession, I have had the opportunity to try different approaches to the learning process with my pupils, and it is through this privileged position that I am able to change the science presented to pupils and can try to make their experience of learning a richer one. The 'reflective practitioner' of the title thus refers to my role in continually developing and deliberating on my own practice.

‘Feminist’ is a term which has come to encompass a wide range of meanings and these will be discussed in greater depth later in the thesis. However, Weiner (1994) identifies the four essential components of feminism as being: political, a movement to improve women’s lives; critical, criticising dominant systems of knowledge; praxis-orientated, involving a practical project of change and creative, imagining different possibilities.

This study involves these key themes which are important in placing the research project in context. The research is political in the sense of having as its aim a desire to improve women’s lives through the creation of a more inclusive science curriculum. It also questions the science which is presented in secondary science syllabuses and the approach to teaching science in secondary schools. As such, it challenges power structures and that which is deemed to be legitimate knowledge in the scientific domain.

One of the most important aspects of praxis is to bring about actual change rather than simply research the issue of concern. The third research question, which asks how a feminist perspective could be related to a new science curriculum, uses examples of changed practice to assess whether pupils might find a different approach more inclusive.

Finally, ‘feminist’ implies being creative and in this study the creative part lay in imagining alternative possibilities to learning about science rather than the often didactic methods of imparting ‘facts’ to pupils in ‘science as norm’. It involved making pupils’ experiences and learning processes part of the course itself by getting them to question the science taught and reflect on what they felt as they were learning. It was this aspect of working through the third research question, that of how a feminist perspective could be related to a new science curriculum, which gave information to policy makers and practitioners which they could implement.

## **Limitations**

In terms of exploring the perceptions of science by pupils and teachers, a small-scale project such as this is necessarily limited in the amount of data



collected and the number of participants involved. Additionally, work on making the science curriculum more inclusive is also impeded due to time constraints, class contact time and the obligation of the researcher/practitioner to the education department to fulfil teaching duties in a state school (Hammersley, 1993). The changes which are feasible within a tightly packed curriculum are therefore restricted but not impossible, and this is one of the aspects of science education which I was challenging.

In this research, the numbers of participants involved were relatively few, thus generalisation from results would be problematic and fall outside of the remit of the research. However, as Schofield (1993) argues, not all qualitative researchers are seeking to produce generalisations or link their work with that of other groups. Specific cases can have their own intrinsic value and comparison with others should not be required in order to achieve relevance.

Nevertheless, current changes in the education system in Scotland, such as ACfE, point to a need for more qualitative research to contribute to the debate on how to improve the learning experience for pupils, and this research offers valuable information for teachers and policy makers towards this goal.

One of the limitations of working as a practitioner and carrying out research in the same school is that I was not only in the position of interviewing my own pupils, which can affect the type of responses (Dockrell, 1988), especially to questions which involve criticism of the teaching involved. I also spoke with science teachers and was wary of conveying implied criticism of their role in the problem of science in secondary schools.

The researcher's personal background also brings its own limitations. As a female science teacher from a white, middle class family, the outcomes from this thesis will necessarily reflect the inherent values of my own perspectives on science and science education. Nevertheless, this position offers advantages in terms of being able to reflect on my practice and to be in a situation with the opportunity to change the type of science which is

presented, creating a learning space where the science and accepted truths are questioned.

### **Organisation of the Report**

This introduction has set out a brief outline of the research which has been carried out into pupils and teachers' attitudes towards science and the contribution which women's studies can make towards developing a more inclusive science. The main body of the thesis gives an account of the research carried out and is organised as follows:

The second chapter discusses relevant literature as it relates to the subject matter of the research and is divided into various sections which explore the way education is socially constructed, the philosophy of science, then how school science curricula have developed. Following from this, the role of the school in the production of gendered identities is explored and the way gender and science are played out in secondary schools. Finally, feminist writing on science will be addressed: how this might inform a new, more inclusive science curriculum and what this particular piece of research can contribute to the existing field of knowledge. The literature review is important in helping to give a clearer focus to how the work I have carried out was shaped by past research. It also indicates where this study stands in relation to other literature and how, through its contribution to existing knowledge, it can extend what is known.

The third chapter is concerned with methodology and discusses the methods and techniques used, which data was collected and how the outcomes from data were analysed. It begins with the pilot study and shows how the research questions and focus of the research changed over time with reflection on what the research was trying to achieve and how this should be realised in practice. It examines the way the focus of the research developed during the time of the initial study to encompass the views not only of pupils but also of the teachers who, as became evident, were crucial to the clarification of the issues involved in the low representation of women in science.

This wide range of perspectives, together with the principles involved in feminist theory, helped to inform debates which I initiated amongst practitioners in the field - focus groups and case study teachers - in looking at the curriculum and processes going on in science teaching to see how these might be challenged and improved. I then explored the idea of developing a new science curriculum, informed by a feminist perspective, with curriculum development teachers and we were able to implement some of these lessons in two first year science classes.

The methodology chapter outlines the way in which the approach to carrying out the research was informed by feminist praxis. The appropriateness and validity of the data is also discussed.

The fourth chapter addresses the research questions by looking firstly at the attitudes of pupils and teachers towards science and analysing the data from interviews. Following on from a discussion of the main outcomes from the data and how these answer the first and second research questions, it comments on the range of views of science from that of a wide, positive stance to those of perceiving science as narrow and negative. In doing so, it moves the research process forward by using these outcomes to shape the next section which is concerned with the third research question on how science could be shaped by a feminist approach and the way that change could be implemented in school.

I worked with colleagues to design alternatives to the science curriculum as used in the secondary school at which I currently teach, which many staff and pupils find boring and unimaginative. By using ideas from feminist studies on science teaching and in collaboration with other teachers, I developed, implemented and evaluated alternative ways of teaching and learning science in early secondary education.

Chapter five is concerned with the presentation and interpretation of data to draw conclusions from the body of data produced. It considers the outcomes in relation to relevant literature and shows how this research contributes to the body of knowledge on gender and science.

The sixth chapter brings together the findings from the research and uses these to make recommendations with regards to changes to secondary

school science. This section also explores significant findings which involves looking at the way the research is timely in the light of recent changes to the Scottish curriculum. These changes have been set out in the Scottish Executive's 'A Curriculum for Excellence', which marks a move away from prescribed, detailed guidelines. Although not obligatory, teachers have tended to follow these guidelines fairly rigidly in the same way as the National Curriculum for England and Wales has south of the border.

Educationalists in Scotland have felt that the guidelines were being followed at the expense of creativity and interest in the classroom and have attempted to redress the balance by opening up the curriculum to change, reducing content and allowing for a more flexible approach guided by children's interests. There are parallels with the research I have carried out, and these will be discussed in this section.

The final chapter reflects on the journey I have undertaken in carrying out the research, its merits and limitations and the way it has affected my own teaching practice.

The research I am working on has the potential to have an effective involvement in the national debate and future science curriculum in Scotland, which aims to bring change through greater flexibility, cross-curricular activities and challenging, interdisciplinary projects. It was with this premise that I felt that the input from this research could help to improve science education for all pupils and therefore make an important contribution to teaching and learning in Scotland.

## **CHAPTER 2: LITERATURE REVIEW**

### **Introduction**

The context of the research shows how the research questions arose and the approach which was deemed to be the most appropriate for shedding light on these questions. This chapter sets out to relate the research to relevant literature in order to show how the literature shaped the research questions, where it is located in terms of methodology and the contribution it will make to the existing body of knowledge on the subject.

The research questions point to the main areas which need to be considered in a review of the curriculum. These ask what mechanisms are involved in encouraging boys and inhibiting girls from choosing physics, how teachers perceive science and humanities subjects, and how feminist approaches could inform curriculum change.

Inherent in the research questions are several key themes which relate to: the social construction of education; the philosophy of science; the way the school science curriculum has developed; gender and science education; feminist theories of science and how a feminist curriculum might be incorporated. In reviewing the literature, it would be useful to look at these five broad areas to see how they relate to the research of this thesis.

The first section will look at key literature in the field of education and the way education has been socially constructed, which sets the research questions in the educational context in which they are located. Following on from this, a discussion on the philosophy of science shows how the production of scientific theories is a dynamic process, one of continuous reappraisal, change and development, rather than a linear pathway towards the production of 'facts', as it is sometimes modelled.

In the third part, the development of the school science curriculum will be outlined to show its wider social context. The way the school science curriculum has grown in status and the choices of topics which are considered for inclusion in the science taught to children is dealt with in this section. This helps to give a broader picture of the context in which the research is situated since that is where my experience as a practitioner lies

and it illustrates the influences which have helped to shape the current structure of science education. Included in this section is an examination of teaching strategies adopted in the humanities and the way in which science and the humanities have come to represent differing, sometimes opposing, factions each incorporating different approaches.

The chapter continues with an analysis of the way gendered identities are produced in schools and considers the gendered experience of schooling and the way the identity of girls affects attitudes and choices made within a school setting. This then leads to a consideration of literature which specifically relates to gender and science education. Such literature includes government initiatives to attract more girls into science classes as well as writing which shows an awareness of the absence of women and is indicative of a liberal feminist approach.

The sixth section deals with feminist theories and science, both radical and post-modern viewpoints, which turn the spotlight critically on the science, specifically physics, which has been offered to pupils. This feminist writing illustrates the way the debate has moved on from perceiving the problem of the scarcity of women in science as lying with women themselves towards a more critical analysis of science and science education. Feminist writers have been critical of what they see as the masculinisation of science by the scientific establishment which explains the low representation of women in this field through unjust practices, biased interpretation of results and discrimination. Feminist theory covers a wide range of perspectives depending on the philosophical viewpoint of the writer and I will illustrate how the different perspectives relate to the literature on gender and science.

Finally, the last section of this chapter will analyse feminist perspectives on the way the debate has moved forward towards creating a feminist curriculum in science. This brings together the main points explored in this chapter and shows how the research questions are further developed through a review of the literature.

## **The Social Construction of Education**

An analysis of pupils' perceptions of science education necessarily requires consideration of the culture of girls and boys and the influences and pressures they face in contemporary society (McKechnie and Hobbs, 2004). Pupils' choices must be looked at in the context in which they are made and sociologists of education have contributed to the debate through their perspectives on the way education has been socially constructed.

Bourdieu and Passeron (1977) write of the way culture, through meaning, is imposed on groups of people in a way that appears legitimate. This legitimacy hides the power relations which exist to reproduce social structures and impose restraint in society. They claim that in education systems inequalities are reproduced through language and meaning:

*“Not only could the teacher not adopt a new language and relation to language without effecting a dissociation of the contents communicated and the manner of communicating them which he cannot conceive of because they were indissociably linked in the manner in which he himself received and assimilated them; but also he could not measure exactly the pupils' understanding of his language without destroying the fiction which enables him to teach with the least effort, i.e. as he was taught” (Bourdieu and Passeron, 1977, p.113).*

As a consequence, power and authority in the classroom can continue to be played out to subsequent groups of pupils. Bourdieu and Passeron (1977) point to the repetition of patterns of teaching which avoid questioning and probing the meanings of the theories which are being replicated in the classroom.

This appears to be particularly relevant to science education since teacher training for a career in science education does not usually involve an analysis of the processes which go on in science teaching. The subjects studied for a pure science degree are not presented in a way which encourages debate or which tackles questions of epistemology. Science education is seen as involving the teaching of a decontextualised curriculum

as a series of facts (Stark and Gray, 1999; Roger and Duffield, 2000) whose basis is unquestionable and whose knowledge is given as being closed to debate or challenge. Pupils are given the theory and 'facts' but rarely asked to question the basis of that knowledge.

The work of Bourdieu and Passeron (1977) notably avoids issues of gender. However, it does offer a theoretical framework which feminist researchers have borrowed from in order to extend their social theory to include gender relations and identities (McNay, 2005). Other feminist perspectives on Bourdieu's theories have re-considered his views on the way power is reproduced in society to look at gender relations, noting both consistencies and instabilities and the resulting possibilities for change (Mickelson, 2003 and McLeod, 2005).

However, this framework is useful as a basis on which to study the mechanisms involved in encouraging boys and inhibiting girls from choosing a physics course. It provides a structure from which to investigate the way in which inequalities are reproduced and become normalised within the system so that self-elimination from particular subjects can seem to be acceptable and accepted.

The curriculum is decided by national governmental bodies to cover a range of topics. The examinations set up to assess the curriculum determine what is included in science teaching and learning. The continually disproportionate numbers of girls choosing subjects other than physics indicates that the way in which science is taught involves one of repeated process.

Other work by Bourdieu (1998) points to social institutions, hence the education system, as sites where masculine domination is perpetuated. In relation to this research, the predominance of boys in the field of science and technology who then go into industry means that men continue to hold the reins of power in society and the status quo is maintained. Bourdieu (1998) explored the idea that in childhood a person develops and grows with an understanding of what and where their place in society will be. This is a process of internalising the notion of what they might achieve, or not, through acceptance of the prospects and opportunities open to them together



with an awareness of their limits of potential attainment. In this paradigm, ambitions are therefore controlled by people's perceptions of the possibilities which are available to them and the constraints which they feel bound by.

In the case of whether to study physics or not, a pupil's decision will depend on their expectations. If the field of science embodies a gendered structure, then a pupil's decision to join this establishment will be taken according to whether they see opportunities for themselves in this sphere. This notion of successful and expected outcomes affecting choice is a useful one on which to develop the research questions.

The work of Foucault (in Rabinow, 1984) also provides a theoretical basis for the investigation of gender and science within an education system. Foucault (1984) argues that discourse (ways of talking and thinking about the world which science is predominantly concerned with) structures social institutions. In the case of the education system then, discursive curriculum practice should be studied:

*“the real political task is to criticise the working of institutions which appear to be both neutral and independent, and to criticise them in such a manner that the political violence which has always exercised itself obscurely through them will be unmasked so that we can fight them” (in Rabinow, 1984, p.6).*

Science education perhaps typifies enlightenment theories of rational meaning, investigative method and production of facts, which are proved by repeated experiment and give rise to 'truths' as Foucault (1984) comments. In the Scottish education context, the national curriculum guidelines set out particular topics for investigation and require pupils to learn and understand particular phenomena according to the scientific explanation given. Pupils are expected to develop skills in how to handle information and carry out experiments using the scientific process. This prescriptive approach to learning about a subject assumes the values of, in this case, the scientific establishment, and the implications for this will be discussed in the following section.

Foucault offers a post-structuralist approach through analysis and deconstruction of the organisation of social systems and the knowledge that they deem to be legitimate. Like that of Bourdieu, Foucault's work makes little mention of gender, but feminist writers (Weiner, 1994; Kenway, 1995) have used Foucault's analysis of discourse to critically examine the gender issues in the education system.

Foucault's ideas of power relations have provided feminist writers with a useful analytical structure through which to explain the way women's position in society has been weakened and controlled by a culturally imposed view of how women should be (McNay, 1992). However, this does not imply that structures are rigid and uncontested. One of the main purposes of a feminist critique of dominant systems and relationships is to bring about a practical programme of change, and this will be addressed in the final section of the chapter which considers how a new science curriculum would look, one informed by a feminist approach to teaching science. Nevertheless, Foucault's work (1984) has been influential in offering an approach to the analysis of social structures, such as education, through the language employed.

Having considered the way the education system has been structured, it would now be interesting to look at the development and the values inherent in science.

## **Philosophy of Science**

Science and technology are the basis for industry and therefore power in society and as such are an important part of modern life. The science which is taught gives the impression of being objective and gender neutral so that anyone, regardless of gender, has the potential to succeed in this field with consistent effort and hard work. The learning tasks associated with science education are characteristically described as hierarchical, logical, and regulated by particular procedures (Ramsden, 1984), with scientific methods of carrying out experiments and drawing conclusions from these being gender free and impartial.

However, experimentation and the interpretation of data to produce theories, which then become facts, are context dependent. Experiments produce results and any conclusions drawn from these will contain assumptions made from the framework in which the researcher is working. One well-known example of this was Einstein's work on relativity which found that calculations based on Newton's laws of motion are only valid for certain narrow ranges of speeds and are at best approximations (Couvalis, 1997). Thus, the nature of science is one of amendment and correction as one theory disproves another. However, if theories are used to justify other theories, can this produce facts and how reliable are these?

This is the premise of the work of Kuhn (1970) writing on the philosophy of science. He states that although problems are posed directly or indirectly from nature, in his view the outcomes drawn from any research carried out are dependent on the paradigms in which the researchers function. By paradigm, he suggests that this includes the general theoretical assumptions, laws, and techniques which particular scientific communities adopt. This will shape the science produced and influence the way observations are interpreted.

Kuhn's view of scientific development is one whereby scientists work to a particular model until this is discredited or proven to be false and is replaced by a new theory. He notes that observations are paradigm laden so that the way in which phenomena are perceived depends on the specific context in which they are working. Thus, the objectivity of science is a flawed notion,

and scientific development is one of revolutions rather than the accumulation of knowledge.

Hence, the idea of universal, unchanging and unbiased theories is untenable. One theory is constructed using other theories and suppositions and thus the resulting “facts” can never be theory neutral. Nevertheless, science remains a powerful authority in western culture and a subject of high status in education, and the way that science has been selected and developed for teaching in schools will be considered in the following section.

### **The Development of the School Science Curriculum**

The research questions look at the perceptions of science by teachers and pupils and the development of a new science curriculum and as such raise questions of how the school science curriculum has come about, what its intentions are and what its purpose is. It would be helpful to look briefly at the way in which science has become a part of the school curriculum, what was deemed to be important and why particular studies were included.

The 19<sup>th</sup> century was a time of prosperity in Great Britain through industrialisation and new inventions. The application of science was seen to be essential for the continued growth of technology, and it was recognised that science should be included in education if Britain was to maintain its economic position in the world. Physics and chemistry were demanded in the school curriculum for the sons of wealthy middle class parents who saw its relevance to medicine and engineering and to an extent this remains true today, with a strong relationship between the choice of physics and its relevance for their future careers (Stokking, 2000 and Cleaves, 2005).

The Thomson committee in the School Science Review of 1920 argued the case for inclusion of science into the school curriculum (Waring, 1979). It was thought that through a heuristic approach, with the spirit of search, training in scientific method would contribute to the ‘development of the mind’. The emphasis on a more practical orientation meant that scientific method should be taught alongside scientific matter, one of process and product. Therefore, the science class began to follow a model in which the

theory was presented, then an experiment carried out, or perhaps a teacher demonstration of an experiment which produced results and the data were used to reinforce the theory. This style of presenting science education has become standard procedure in contemporary science classrooms.

From the 1950s onwards, there was a trend towards greater inclusion of school science and a centralised curriculum with government issued guidelines. The Science Masters Association's policy statement of 1957 recommended that 11-18 year olds follow a course in natural science which included physics, chemistry, biology, and astronomy with separate sciences for 'O' level.

In Scotland, schools adhere to a similar policy of teaching environmental studies – that of society, science, and technology through the national 5-14 guidelines which aim: “to develop a scientific approach to problem solving, encourage critical thinking, and develop positive attitudes to science to appreciate its contribution to and impact on society” (Curriculum and Assessment in Scotland National Guidelines (1993) Environmental Studies 5-14).

These guidelines, though not obligatory, as in the case of the National Curriculum in England and Wales, are nevertheless used as the basis for most secondary school science programmes in Scotland, and, similarly, topics are arranged in standard units of chemistry, physics, and biology within an integrated science teaching programme. Beyond this level, after the age of 14, pupils study individual sciences.

There is some evidence that at primary level there is generally a positive attitude towards science. Murphy and Beggs (2003) carried out a survey of one thousand children between the ages of 8-11 and found that all science topics were enjoyed by the youngest children but that there was a decline in enthusiasm for science as the children progressed to upper primary. Murphy and Beggs (2003) noted that the primary teachers found science in general and physics in particular, difficult to teach, which may point to the underlying reasons for this shift in attitude.

Nevertheless, in the Scottish context, Stark and Gray (1999), Reid (2003) and Reid and Skryabina (2003) found that even though late primary pupils

looked forward to studying science at secondary level, these attitudes changed markedly by the end of the second year at secondary school. Again, in terms of creating a new curriculum, this highlights the crucial stage of intervention, as being that of the first few years of secondary level education.

A large scale study by Spall et al (2004) of over 1000 pupils in the UK also found a decline in positive attitudes towards physics and biology with physics showing a greater decline than biology. The perception of physics for pupils was that good maths skills were required and that although a study of physics might lead to more career possibilities, it did not make the subject a more attractive option. This decline in interest in science was also found in a comparative study of science classes in Sweden, England and Australia by Lyons (2006) who examined pupils' conceptions and attitudes towards science. This research demonstrates that the problem exists at a wider level, and, again, content overload, lack of relevance, and difficulty are cited as the main contributors to this problem.

The questions to be asked then are: what happens to pupils in the first and second years of science education which makes them switch off from science, is this to do with the science process and content that is being taught or identity and emerging adolescence, and what would sustain pupils' interests in science? These questions need to be researched since the low numbers girls opting for science courses, particularly physics, is concerning.

The problem of rejection of physics by girls at this level is highlighted by Kelly (1981) who notes that once they have left this field, it is unlikely that they will be able or keen to return to it. She emphasises the particular problem in Scotland, where subject choices are made at the age of fourteen and:

*“girls often abandon science willingly and eagerly. But they do so against a background of sex stereotyped assumptions and expectations which renders the notion of ‘free choice’ largely meaningless. The channelling is apparently voluntary but that does not make it any the less deplorable”. (Kelly, 1981, p. 136)*

Kelly contends that this masculine image of physics is one which discourages and disadvantages girls in classes and, in later work, identifies four factors which she sees as contributing to the construction of masculine science (Kelly, 1987). These comprise of: physics classes which contain a majority of boys, the presentation of science using the male as norm, which in turn leads to classroom behaviours establishing physics as male, reinforcing masculinity in its participants, and projecting ways of thinking about the world which embody masculine points of view. Kelly argues that all of these characteristics help to maintain and perpetuate the masculine image of physics. Her conclusion is that if science were presented in a more humanistic way, then it might be possible to engage girls in physics lessons and the resulting science too would benefit. Although this work was written some time ago, its findings and implications are still relevant to contemporary studies, given the current uptake of physics by girls.

Recent research on secondary pupils' perceptions of science are commented on by Barmby and Defty (2006) who note that the numbers of pupils taking Advanced Level physics has fallen by some 38% in England and Wales over the past 20 years. The authors found that physics is perceived by girls to be the least popular science and that there is a need to address this problem.

However, the problem is not just confined to physics, but also to the other sciences. In Scotland, the numbers of pupils taking Higher Level physics, the examination allowing university entrance, has dropped by 30%, but chemistry by 38% and biology by 27% over the period from 1987 to 2006 (Scottish Qualifications Authority). The figures suggest that there is an increasing rejection of science by all pupils in favour of other subjects in the curriculum. There are, therefore, major concerns for the numbers of science pupils in general which have been steadily decreasing since the 1980s.

The content of school science is one aspect which may contribute to the decline in numbers, according to Gilbert (2001) who argues that the syllabus is aimed at those pupils who will follow science subjects to university level, and that it is not relevant for many school pupils who will not pursue a career in science.

Similarly, Osborne and Collins (2001) found that there was an over emphasis on content, which did not challenge pupils and which involved repeated work and experiments. The pupils did, however, enjoy parts of the syllabus which they perceived to be relevant and this points to ways in which the curriculum might be changed in order to become more inclusive.

To summarise, the statistics point to a need for research which looks at pupils' attitudes towards science. This is emphasised by Osborne et al (2003) in the UK and elsewhere in Europe (Krogh, 2005). The issue of relevance of both scientific knowledge and practical investigations to school pupils is one of the main concerns for this research and will be addressed in subsequent chapters.

### **Schools and the Production of Gendered Identities**

Education has an important part to play in terms of our development as individuals and our sense of ourselves and who we are. Moreover, our identities with regards to class, race, and gender might also determine our experience of education. Secondary level schooling coincides with a time of great changes (both physiological and psychological) in the development of children and young people and has a crucial role in the way gendered identity is produced.

When children progress into their teenage years, their self image becomes more important and peer group pressure exerts a greater impact. McRobbie (1991) has written widely on the subject of identity and found that generally for many girls, but also for working class girls in particular, the choice of subjects at school can be used to emphasize their femininity. When related to physics then, which are seen as male dominated, a rejection of this subject can be perceived by themselves and others as a reaffirmation of their female identity.

One way around this has been through the use of initiatives involving the teaching of science in single-sex classrooms and these have met with some success, both in the UK (Gillibrand et al, 1999; Younger and Warrington,



2002; Robinson and Gillibrand, 2004), Australia (Parker and Rennie, 2002), New Zealand (Harker, 2000) and Europe (Brutsaert and Van Houtte, 2002).

However, caution is advised when looking at higher attainment outcomes since other factors such as achievement at entry level had a greater effect on performance. In spite of this, there does appear to be confirmation that single-sex groupings can be beneficial for girls and boys, creating a more positive learning environment. Perhaps the main outcome from the above research was to point to importance of the role of the teacher in engaging the pupils and using strategies which appealed to the learners.

Young children continue to perceive science and scientists as a predominantly masculine domain (Kahle and Lakes, 2003 and Buldu, 2006) and teachers have a vital role to play in the creation of these perceptions. This idea of physics being associated with masculine values is an interesting concept and one which helped to shape the research questions.

Physics is also a high status subject in the curriculum with a reputation for being a difficult field of study. Murphy and Whitelegg's (2006) review of research into girls and physics notes that for girls in particular there is an increased perception of physics as being hard and also an increased sense of being inadequate in this subject, which seems to affect their self-esteem.

The image of working as a scientist is tied in with self perception, and if pupils cannot relate to that image, they will favour other choices of employment (Cleaves, 2005). The lessons, therefore, for the teachers of school science are to consider how it is perceived by pupils and how it can be made more accessible and thus more inclusive for all learners.

Recent statistics, which point to the under achievement of boys across the curriculum in comparison with girls, have led to a focus on research concerned with raising boys' attainment (Bennett, 2003; Dillabough, 2003). This has made the concept of the exclusion of girls one of lesser priority, particularly when the form of exclusion tends to be withdrawal from classroom work and subtle disengagement with a subject rather than overt emotional and behavioural problems acted out as a challenge to classroom discipline. With a focus on league tables and on the problems for boys,

girls' disengagement can be ignored since its expression in class is inclined to be less disruptive and obvious.

The time of adolescence can be particularly difficult for girls who experience a period of dissociation from themselves and other women in the development of their identity (Gilligan, 1995). This analysis asserts that girls are in a process of changing relationships in order to establish their femininity in a patriarchal society at a crucial time in their education when choices about future careers are being decided. The implications for education then are far reaching if girls are to be encouraged and engaged in a subject at a time in their lives when they are in the process of reaffirming their identities.

Some girls face difficulties with education at this point in their lives, and Lloyd (2005) offers an exploration of the ways in which girls experience the school system which relates to their social identities. Labelling girls as problems at this stage is unhelpful and does not offer a way forward. Lloyd (2005) also argues for a reassessment of the way 'problem' girls are excluded from school and urges policy makers to consider girls as well as boys and the ways in which they are failing to realize their potential when looking at underachievement and disaffection, rather than the current focus on boys.

This stage in girls' lives may, however, go unnoticed by teachers (Osler and Vincent, 2003) as girls' resistance to schooling tends towards passive disengagement. Although they may be present in class, girls are more likely to be quietly avoiding the work of the lesson rather than exhibiting any confrontational and behavioural difficulties more often seen in boys. However, this exclusion from work in class does not mean that the needs of the girls are of less importance and should be ignored. On the contrary, this rejection of class work instead requires teachers to be alert to the dangers of disengagement by girls.

Cruddas and Haddock (2003) offer alternative approaches to teaching girls by giving 'voice' to those who have not been included. They stress the importance of understanding the needs of the girls through group work, which benefits girls' emotional intelligence. This type of activity of group

work on a particular topic is one which can be transferred to the science class and is a strategy which helps to inform the research questions.

The idea of emotional intelligence came from the work of Gardner (1993) who saw the teachers' role as one of fostering all intelligences, including emotional intelligence. Goleman (1996) understood this to mean that the responsibility of the education system was greater than that of imparting knowledge. Instead, it should encourage the development of all life skills. The implication from his work was that young people could not learn if they did not feel good about themselves, and his research demonstrated that the learning process must integrate emotional and cognitive centres.

If relational and affective development affects our ability to learn, the implications of this then are that young people need environments that encourage them to develop their potential. Girls' voices can be encouraged in the classroom through activities which value their contributions and allows them to be heard, and this issue will be explored through the research questions as a way of making science education more inclusive in practice.

It is possible, according to Warrington and Younger (2006), to investigate issues of raising boys' achievement whilst maintaining a commitment to feminist principles and indeed benefit all pupils by developing a more inclusive practice in mainstream schools as a result.

## **Gender and Science Education**

Women have, until recent times, been actively and subtly discouraged from working in science. Their exclusion from scientific societies and universities until the late 19<sup>th</sup> century meant that any achievements in this field came in spite of almost insurmountable barriers put in their way. Whilst nature was considered to be female, it was to be "bound into service" to the natural philosophers. Henry (1997) suggests that the development of science did not deliberately set out to subjugate women:

*"But the sexual metaphors which occurred to the natural philosophers reflected and helped to shape attitudes to*

*legitimate knowledge and appropriate knowledge  
producers which remain gendered to this day”*

*(Henry, 1997, p. 92).*

Hence, rather than objective and value free, science contains gender biases within its structure and text. That science, which invokes a philosophy of impartiality, objectivity and rationality, should be gendered is an issue which I explore in this research.

Feminist scientists (Haraway, 1989; Keller, 1996) have shown how scientific writing embodies the cultural values and dominant beliefs of the society. Women's studies have involved looking for alternative approaches to the male dominated and orientated scientific establishment, and feminist writers have discussed this area of discrimination and inequality from their various viewpoints. This ranges from liberal feminist writers concerned with issues of equality and women's rights, to socialist feminists who focus on the relationship between education and the way labour has been sexually divided, and from radical feminists who see the reproduction of patriarchal power in the scientific establishment and seek to challenge this to post-modern feminists who question the basis of western thought, including science. Their writing on these issues reflects the different feminist perspectives, and this will be discussed in more detail in the next section.

One of the most significant official reports into women and science, which prompted the research questions, was one undertaken by the European Commission. The European Technology Assessment Network (ETAN Report, 2000) on Women and Science came about because of the concern for the continuing low uptake of science by women and why these women were then leaving science in large numbers rather than continue their careers in this field.

The document was written primarily by women scientists, and there is little analysis of the nature of science itself in the report. Most articles in it are concerned with the problem of equality of opportunity and blame the hierarchical structures in science departments with male dominated research facilities and male controlled access to research funding limiting the work of female research scientists.

In a similar vein, the Greenfield Report (2002), a study of women in science, technology, and engineering in the UK, stresses the drawbacks of losing or not attracting a female workforce in terms of loss of opportunity for both women and employers. Again, like the ETAN Report, it concentrates on access and conditions for women in science careers.

The UK parliament, (House of Lords Select Committee on Science and Technology – Third Report, 2000) addressed the problem of public understanding and awareness of science and technology in society. One chapter relates to “Special initiatives for women” but makes the general comment that: “women often have distinctive viewpoints which may go unrepresented ... unless a special effort is made to include them” (Chapter 5, Engaging the public, paragraph 5.63).

All of these official reports stress the unjust system and the way women are marginalised within it but do not question the science and technology which develop from that system. In this respect, they typify a liberal feminist approach concerned with issues of access and equality but not with challenging the basis of science and scientific theory.

One of the main purposes of this research project is to question the science that is taught and the methods used to teach it in the classroom. It moves the debate on from liberal feminist concerns of asking why girls are not choosing physics to asking what it is about physics that is unattractive or unwelcoming to girls.

This was an area discussed through research by Thomas (1988, 1990) and Ferriera (2003) of higher education. The authors found that university students had very different experiences in science and humanities departments. They found that there were few women working in physics departments due to lack of encouragement and feelings of being unwelcome there. This work would appear to confirm the experiences of women as minorities in the scientific establishment, as noted by the ETAN report. The experiences of being in a minority, of isolation, and the lack of support in continuing physics studies would account in part for the large drop out rate of women in this profession. However, this is at a stage where tertiary

education level students have already made a choice to study the sciences and have embarked upon careers in this area.

Some of the literature suggests that the problem is concerned with access issues. Garratt (1986) analysed the process of teaching and learning in science classrooms and commented on its structure, content and assessment, criticising the processes in science education but concentrating on adapting the context to make it more attractive to girls in order to encourage their continuing participation in this field. This writing illustrates the way in which the debate on gender and science has been informed and developed by feminist writing. It does so from a liberal standpoint and relates to access of opportunity, which were the approaches taken at this time. Nevertheless, more recent work by Reiss (2000) shows that this type of debate continues in current classroom teaching and learning, suggesting little progress in the intervening years in terms of content and approach.

Science departments are characterised by passivity, where the learners are required to study material of an abstract nature and where learning is tightly controlled and prescribed (Weiner, 1994). In addition, many initiatives to encourage more women into science (such as Girls into Science and Technology) have largely been unsuccessful. One reason is the lack of engagement by the teachers, mostly male, who did not perceive of any problems with their classroom teaching methods or presentation of the subject (Weiner, 1994).

When the teaching of science to all pupils is legally binding for schools, this serves to confer upon it the status of a higher skilled and important subject (Miles and Middleton, 1995). In the Scottish education system, science, technology and home economics are allowed 30% (the largest percentage of all subjects) of the time allocated to study, in the first and second years of high school which also reinforces the privileged position of science.

A more recent piece of research based on OCR (Oxford, Cambridge and RSA exams) by Bell (2001) also offers an insight into why girls are poorly represented in physics. Bell's analysis of the responses to questions in physics noted that certain questions were more easily answered by boys, since examples in the questions used would be more familiar to them

because of cultural and social norms. He acknowledges that exams favour boys' experiences, stating:

*“Given the existence of differences in attitude and early experience, it is unsurprising that there are gender differences in certain parts of science education. There are some curricular areas, such as electrical circuits or earth/space topics, where it might be impossible to construct items for which male candidates had not had more relevant experience given current attitudes and preferences” (Bell, 2001, p. 485).*

Bell does not criticise the content of the physics syllabus or the type of questions used by the board, instead blaming girls' under-performance in physics on cultural experience. The analysis comes from a “male as norm” stance, where the experiences of males are used as the natural starting point for exam questions and content of the physics syllabus.

Stewart (1998) also comments on the masculine contexts of questions in physics and points out that the problem then lies with the physicists, rather than the girls in changing this situation. This concept of changing the science taught is one which informs the research questions and will be developed further in the final section of this chapter.

The advantages which boys have through greater exposure and experience of the context of questions in physics examinations is noted by Preece et al (1999), though the authors appear to accept this as irresolvable: “test content should be selected by how educationally important it is, not by the consideration of gender differences that it might or might not produce” (Preece et al, 1999, p. 985).

The questions of who decides what is “educationally important” and why certain topics are included while others are left out of the syllabus are not raised. Instead, the author merely describes the situation, without offering alternative solutions or approaches. This article by Preece et al (1999) demonstrates a need for these questions to be asked and its relevance to this thesis was to highlight the necessity for more discussion with teachers, pupils and expert groups about what they felt should be included in their

science classes and what they would change to make physics more attractive.

All of the above studies reflect liberal feminist viewpoints which appeal to equality of opportunity (an outline and analysis of feminist approaches is given by Lown, 1995). Their emphasis is on reforming existing structures for the teaching and learning of science. This is based on acceptance of the systems in operation, with the addition of certain changes which aim to improve them.

However, Longino and Hammonds (1990) consider that instead of asking:

*“what is it about women and women’s lives that have kept them from doing science?”*

we should ask:

*“what is it about science that has limited the participation of women and by extension, other marginalized groups?”*  
(Longino and Hammonds, 1990, p. 83).

For feminist writers and for this research study, the second of the two questions is the vital issue at stake and which must be addressed if women’s lives and science are to be improved. The next section will look at feminist writing which focuses on the western science tradition criticising its positivist assumptions, advocating an analysis of the nature of science and how it has come to be an imposing and powerful force in western society.



## **Feminist Theory and Science**

Reflection on gender and science and the way science has developed are areas in which feminist writers have offered a new perspective to the ‘women and science’ question.

Feminist theory takes a different approach to analysing the scientific establishment and questions accepted ways of working with the object of improving women’s lives and improving science. The questions of “whose science, whose knowledge? (Harding, 1991) and, it might be added, “for whose benefit?” underlie the stance from which feminist critiques of science have been undertaken. In the case of this thesis, the focus is then concerned with secondary school science, what is taught, how it is taught and why it is taught.

Feminist approaches have the aim of instigating change and achieve greater equality though analysis and questioning the basis of knowledge, accepted ‘truths’ and the hierarchical structures which exist in society. They seek to encourage a “critical capacity” (Weiler, 1995, p. 24) in people, allowing for analysis of their subjectivity in society, a consequence of privilege or oppression or history. Such a stance involves examining how, as a result of class, race or gender, we are positioned in society, and then using this information to break with these constraints, seeking better alternatives.

A post-modern feminist stance celebrates the differences and diversity which exists between groups and in individuals, where identities are multiple and dynamic in nature. Weiler (1995) makes this point by stating that:

*“feminist theory validates difference, challenges universal claims to truth and seeks to create social transformations in a world of shifting and uncertain meanings”*

*(Weiler, 1995, p.23).*

Feminist writers like Harding (1991) and Hughes (2001) adopt the perspective of holding up science to scrutiny, which they see as being crucial for changing the status quo. They see the problem as lying with science itself: what counts as a valid problem, what is important as a

scientific question, its structure, content and the way it is taught. They focus on the way science in the western world is associated with masculine values and examine western science from feminist theoretical perspectives, deconstructing it to show inherent gender bias.

Feminist commentators raise questions of epistemology and analyse the value claims of western science, showing the socially constructed nature of science and it is through the adoption of this approach that I have carried out this investigation to explore the science education which children receive in the classroom. Feminist theory has tended to move on from liberal notions of equality of opportunity and access towards associating itself more with post-modern philosophy. Both reject modernist ideas and disassociate themselves from notions of fixed, universal truths and the assumptions of science from the modern era, such as its claims to produce facts. These have been deconstructed to show the cultural and historical bias inherent in these claims.

However, there are limitations to adopting post-modern strategies in attempting to investigate gender and science since both terms become meaningless when reduced to cultural constructs. As Skeggs (1991) states:

*“postmodernism impairs the construction of projects such as feminism. Whilst the problems with the homogeneity of the term ‘woman’ has been recognised; political engagement still renders it necessary. If subjectivities are multiple and changeable; if power is diffuse; if legitimation is only local then the ability to challenge is constrained to the particular. Feminists would argue for struggle at the particular: but also at the general, across a range of sites, and at a number of levels.”*

*(Skeggs, 1991, p261).*

How then are feminist researchers to use the ideas of questioning and deconstructing terms from the post-modern approach to improve women's lives?

Post-modern feminist analyses of gender and science challenge traditional assumptions and structures through deconstruction of language. They deconstruct the meaning of words through reversal of the terms and then displace the logic on which the opposition is based. Hence, meaning is made explicit through contrast, so that with opposites such as black/white, emotional/rational, male/female, in the hierarchy of values which is inherent in the terms, the first has superiority over the second. In this way, post-modern feminists question the binaries of modernist thought to dismantle their meanings and expose the underlying suppositions of inferiority of the other.

As Gilbert (2001) points out, where dichotomies are made, such as male/female, rational/irrational, then the underlying assumption is that the first is the norm and the contrasting second term is subordinate to it. Gilbert (2001) recommends the deconstruction of the terms 'gender' and 'science' to expose the underlying assumptions contained within them. There is however, a dilemma for feminists adopting a post-modern approach, for in trying to expose the failings in Western science, through deconstruction, one must also deconstruct the assumptions inherent in the term gender. In deconstructing "gender and science", the terms become so fragmented as to be devoid of any meaning and how then can the situation of girls in science classes be improved?

This concern is articulated by Yates (1993) when she states:

*"that the continuing interest only in unpicking the silences and deconstructing the categories, disowning even the term 'woman', is a dangerous one for feminist practice. What association, what movement for change, it is said, can persist on such a basis?" (Yates, 1993, p.169).*

However, McNay (1992) welcomes this exploration of whether a post-modern or poststructuralist perspective is a useful one for feminists:

*"the uncovering of tension and conflict is healthy in that it prevents closure, sustains reflexivity and continually pushes the debate between feminist and poststructuralist*

*theory on to new and challenging ground”*  
(McNay, 1992, p.10).

Perhaps the most useful employment of deconstruction from post-modern feminist thinking is towards emphasising the importance of questioning the basis of the structures which exist in society, how they have come to be dominant and, in this research, critically analysing how the science which is taught and prescribed in schools has come to be, then to change it to be more gender inclusive. According to Weeks (2004), the most important issue is that of moving beyond the modernist/post-modernist debate towards improving women's lives.

Within science itself, a critical approach is not a technique which has been widely utilised as it is in the humanities, in seeking to question meanings and intentions. The questioning in science can be thought to take place within the system, using science's own rules e.g. in verification of experimental work, which is assessed on whether it is able to be reproduced and whether the conclusions drawn are shown by evidence from results. However, this seemingly neutral, objective technique is, according to Harding (1998), only:

*“the illusion of the unity and universality of modern science”* (Harding, 1998, p.176).

The science which has come to be assumed as universal and which claims to give a true explanation of the world around us contains within it the assumptions and values of the society which it emerged from. Since science grew from European traditions, it will embody the ideals from this culture. It therefore cannot be value free and uncontaminated by the politics, pressures and history of the culture in which it is developed.

Hence, the context, the culture and modes of thinking of the people engaged in the work are crucial to the science which emerges. What is then required is a critical analysis of Western science. Harding (1991) considers what a feminist science would look like and offers three possibilities.

The first, feminist empiricist philosophy, is one in which the flawed science is corrected. This assumes enlightenment approaches in which science is

neutral and any biased science has arisen due to bad practice. Harding feels that feminist analyses of science have moved past this understanding to the position we are now in, one of feminist standpoint theory (Harding, 2004). This tries to construct knowledge from the perspective of women's lives. Only then, it is argued, will we have a more objective and less biased science. This stance requires the acknowledgment that our beliefs are located socially (Harding, 2004).

A third viewpoint given by Harding, of feminist post-modernism, considers that the first two approaches do not go far enough in breaking down the assumptions of inherent enlightenment attachments in Western science. However, as this is: "studiously uninterested in advancing feminist sciences" (Harding, 1991, p.56), it seems that the second approach has more relevance for this thesis. As discussed earlier, a post-modern approach involves the deconstruction of terms such as women and science and if injustices are to be redressed, in terms of creating a new science curriculum, then an analysis of the situation involves acceptance of a shared meaning for these labels, rejecting the use of a post-modern approach.

Instead, Harding (1991) identifies the need for 'strong objectivity', rather than the lack of scrutiny which exists at the moment in the consideration of science.

*"Feminism needs sciences that are more objective than the knowledge seeking practices of androcentric, bourgeois groups in the west which have been passed off as objective, dispassionate, disinterested, universal science" (Harding, 1991, p.307).*

Whilst it is an attractive proposition to recreate a new science from a feminist perspective, this is in itself problematic. The inherent assumptions in feminist standpoint are that there is a standpoint, which can be agreed on. As has been pointed out, there is not one feminist stance, but many. The question then is whose standpoint?

This dilemma is articulated by Aziz (1995):

*“on closer inspection supposedly universal interests turn out to be those of a particular group of women”*

*(Aziz, 1995, p.165).*

In the past, feminists have been criticised for speaking out on behalf of ‘women’, when the women in question are those often in a position of privilege who generalise and vocalise their views to encompass all women. Likewise, a feminist science implies in itself that there is a truth to be found, knowledge to be discovered and facts to be stated. There is clearly a dilemma here, for in trying to articulate a feminist standpoint, Harding uses ideas from the enlightenment of an objective, reliable foundation of knowledge as a basis.

In other work, Harding (1998) followed on from this analysis of science to look at the history of science systems and concluded that western science is used to show other belief systems as backward and irrational. Local theories of knowledge and knowledge systems and beliefs are dismissed by Western science, which embodies the white, male heterosexual establishment.

My own experience of working within different cultures, particularly those of poorer countries of the Caribbean and Pacific, bears out Harding’s claim that local knowledge is not recognised or ignored. In these cultures, the people had a rich and complex system of explaining natural phenomenon and using medicines based on local plants and herbs, but this was overridden by the western scientific theories and medicines which were given greater status and emphasis. The local knowledge was dismissed by both teaching staff and various governments as being superstitious and unscientific. This cultural hegemony in which western science was deemed by people holding positions of power to be superior and therefore of importance in children’s learning, ensured that local beliefs were relegated to positions of lesser worth and treated as of no consequence or of little value.

Harding argues that it is impossible for science not to reflect the culture from which it emanates when even qualities like abstractness indicate cultural features, rather than no culture. She states:

*“Even if it were the case, impossible though it be, that modern sciences could bear no such cultural finger-prints as the kinds marked above, their value-neutrality would itself mark them as distinctively European” (Harding, 1998, p.61).*

An acknowledgment that the science produced by research has socially constructed values would offer some transparency to the conclusions drawn from work in this field and one of the aims of this study is to bring into question the science that is taught and deconstruct it to show these values. Harding’s work contributes to the research questions which are being explored in this thesis through its emphasis on questioning the science that is taught which girls are rejecting in favour of other subjects and looking at what is it about physics which boys tend to find attractive.

Like Harding, Flax (1995) reflects upon the growing uncertainties of knowledge and beliefs. She writes:

*“Feminists, like other post-modernists, have begun to suspect that all transcendental claims reflect and reify the experience of a few persons – mostly white, Western males” (Flax, 1995, p.145).*

Hence the only way to expose bias, particularly gender bias is through deconstruction of the assumptions on which knowledge is based. The theory is that as women move into areas hitherto isolated from them, they will question more and dispute the hindrances they face, to bring about change. However, the problem is then that since less women are opting for physics, there is less chance of this happening.

Two possibilities present themselves, either an acceptance that there is little which can be done about the status quo as science and science education are so entrenched in our society and culture that any change is unlikely or to see the potential for improvement in the situation for girls and science education through including their voices and changing the learners’ experience.

Haraway (2004) stresses the need for the latter approach:

*"There is no single feminist standpoint because our maps require too many dimensions for that metaphor to ground our visions. But the feminist standpoint theorists' goal of an epistemology and politics of engaged, accountable positioning remains eminently potent. The goal is better accounts of the world, that is, "science".*

*(Haraway, 2004, p.93).*

The implications for science education are that a greater exploration of the nature of the science which is taught is required. The next section takes this issue forward by looking at alternatives for science education, using feminist critiques and different approaches to learning science.

### **Towards a New Science Curriculum?**

The question of whether we can move towards a new science curriculum then leads to two questions of why it is important and how we could achieve this.

Firstly, the importance of women's engagement in science is articulated by Barr and Birke (1997) who note that women cannot afford to remain apart from the process of developing science since this stance:

*"effectively leaves the terrain of science uncontested. And not only does it fail to challenge science, it also fails to challenge the ways that science affects us all".*  
*(Barr and Birke, 1997, p.88).*

The case for changing the science curriculum is also argued by Harding (1986) who feels that school science is presented in a depersonalised, detached way:

*"More males are attracted into science even where it appears that opportunities are equally open to both sexes; but the males may be of a particular personality type and use a cognitive style which limits creativity. Not only does this selective process disadvantage women but it limits the*



*development of science and may create hazards for society". (Harding, 1986, pp. 165-166).*

This writing draws on the work of Bourdieu and Passeron (1977), which was discussed earlier, in the way power is reproduced through repetition of practices and product. It also makes a strong case for the development of an alternative approach to science teaching in schools, urging the involvement of women in changing science.

How then can this be realised in practice? Birke (1986) puts forward an alternative:

*"If we had a different kind of science, one which emphasized respect for, and cooperation with, the nature it studies, then more girls or women might be drawn into it." (Birke, 1986, p.199).*

This wider approach to science teaching is one put forward through advocates of the study of Science, Technology and Society (STS) in science education (Solomon, 1993; Aikenhead, 1994). STS encompasses a wider range of issues which are affected by and affect science, such as economic and environmental factors, which impact on our lives. Additionally, greater emphasis on discussion of both the benefits and disadvantages of science, a multi-cultural approach and the inclusion of personal values and opinions are all cited as important features of STS but which are rarely raised as part of mainstream science studies. The authors highlight the positive outcomes from pupils when children are engaged and feeling that their contribution is valued in addressing the wider issues.

Curriculum reform can involve one of giving pupils more independence in the classroom (Roychoudhury et al, 1995). The importance of children being given more control over what they did in a science classroom was noted:

*"gender inclusive science teaching may become more meaningful when pupils are given an opportunity to develop an sense of autonomy and control". (Roychoudhury et al, 1995, p.918).*

Similarly, Schwartz and Sadler (2007) note that pupils have a higher level of engagement when they have more control over the ways in which they can carry out work in science classes.

Hughes (2001) writes that:

*“socially relevant and more constructivist science can generate a wide range of scientist identities and thus open the way towards a more inclusive science curriculum”*  
(Hughes, 2001, p. 288).

This is the approach taken by this study in questioning the science as it is taught in schools.

In the same way, Barton (1997) writes about incorporating feminist theory in her chemistry classes. She attempts to reform science education by engaging pupils in a critical analysis of science as it is conventionally taught.

The Salters’ chemistry project which adopts a context based approach to learning about chemistry has shown some success in engaging pupils by making the subject more relevant (Bennet and Lubben, 2006), though Hughes (2000) adds a note of caution warning that the possibility of creating a more gender inclusive approach depends on the way the course is presented: that greater discussion and debate should be emphasised to strengthen its message.

To summarise, closer ties with nature, pupil-led investigation, socially relevant science and questioning the science and science education presented might be useful parameters from which to develop a more inclusive science. The role of the teacher is then the crucial element to implementing change.

Greater co-operation and communication in science classes can improve attitudes towards science by both boys and girls (Labudde et al, 2000). Similarly, Zohar and Sela (2003) found that by decreasing competitiveness in physics classes, girls were more engaged in the subject.

Research undertaken by Hoffmann (2002) found that all pupils were more engaged in a particular topic like pressure when examples from medical physics were used, rather than technical applications for studying mechanics. Hoffmann acknowledges that in physics courses, both the teaching and the syllabus principally involve the interests of male pupils. However, she stresses that the syllabus can be interpreted in different ways so that if physics is presented with applications to human biology, medicine or natural phenomenon, it could be more attractive to girls, without any disadvantage to boys or loss of content. This marks an attempt to take the needs of girls more into consideration, but is only a starting point and affects one small area of the physics syllabus. Nevertheless, it illustrates that science can be interpreted in different ways, without exclusion by gender and this is an important issue for this research.

A useful starting point in the development of the curriculum would be to begin with pupils' experiences and involve history, literature as well as the culture of women and men with different beliefs and backgrounds. By using women and women's experiences as a focus, as well as those of men, we might redefine our curriculum to include everyone (Rosser, 1990).

This notion of adopting a similar approach to science as is taken in humanities subjects, with greater discussion of values and opinions, is considered by Letts (2001) who suggests that science lessons should also encourage critical reading practices. Without this,

*“our science lessons are partial, science can unwittingly continue to seduce us, and we perpetuate a view of science that normalises, in this case, hegemonic heterosexual masculinity” (Letts, 2001, p. 271).*

Although the research I have carried out is concerned with secondary school level science, the reforms for college courses proposed by Tobias (1990) resonate with the objectives of creating a more inclusive science. Tobias (1990) worked on a pilot programme with students who, although they had been successful in school science, had opted for humanities subjects at college. The students were asked to critique an introductory chemistry class and comment on their impressions of and reactions to the course. They

reported feeling that there was no overview or context given of the science presented and missed the classroom discussions which were lacking in science but which they had felt gave them a sense of community in their chosen subjects.

Tobias's (1990) work emphasises the point that science educators need to address the questions of why science is taught, what is taught and to whom. In addition, it is also important that children should have an understanding of the nature of science (Driver et al, 1996). In trying to encourage understanding, science teachers need to explore some of the concepts which children bring to the classroom. Driver et al (1996) suggests that practitioners should strive to encourage scientific literacy through having pupils question their own views and theories, rather than passive acceptance of facts. This helps to increase public understanding of science and enables people to make informed judgements about the efficacy, limitations and claims made by scientists.

The need for change to the curriculum in science education has been shown to be both possible and necessary. Also the way in which this might be carried out has been suggested though literature describing ways of moving the issue forward. It also points to how the third research question, that of changing the science syllabus using feminist perspectives could be developed and this will be returned to in the next chapter.

## **Conclusion**

To summarise, the literature surrounding the field of gender, science and education covers a wide range of perspectives and is an area which has been commented on extensively due to the importance of science and technology in western society.

Firstly, sociologists comment on the way in which schools are sites through which culture is reproduced in societies, with male dominance being maintained through the education system and through the presentation of subjects like physics. Feminist writers have extended this standpoint to criticise the masculine image of science and the way physics is regarded as a high status subject, given their connection with industry and power in society.

Differing feminist perspectives have been shown to range from a liberal feminist stance of equality of access and opportunity for all pupils to a post-modern feminist perspective which looks to a deconstruction of the science in Western society to show inherent gender bias. This however would not lead to an improvement for women unless a more inclusive science and science education can be developed, deconstruction being a first step, then a reconstruction of an alternative approach to science teaching.

Perhaps the main purpose of such an analysis of the literature is that in the process of trying to understand how the low representation of women in science has come about and continues to be problematic, the inherent injustices within the science education system are exposed and new approaches are found. Whilst some measures have been taken to address this problem, there still remains a need for continued debate and development of science education in our schools. In this way, the research questions which this thesis poses, that of how science has come to be gendered and what a feminist science would look like, are still relevant and pertinent questions. The following chapters show how they contribute to and build on the current literature which has been reviewed.

## CHAPTER 3: METHODOLOGY

### The Research Issues

The issue of science and gender has been widely investigated from different perspectives, each involving different research methodologies. Methodology refers to both the theory and an analysis of the research process. It addresses the theoretical framework as well as the link between this and the methods employed in the research for gathering the data. This chapter sets out to explore the relationship between feminist research methodology and the methods used in this research to investigate the low participation of women in the physical sciences.

The research questions developed from this issue beginning with general questions as to how and why this situation had come about towards the specific questions of:

*What are the mechanisms which both inhibit girls from choosing physics and encourage boys to pursue this subject at post-compulsory level?*

*How do teachers perceive and relate science as a subject in the curriculum?*

*How could a feminist perspective contribute towards a new science curriculum in order to change the approach to teaching physics?*

The research involved the use of interviews, where I spoke with teachers and pupils, and using this data, identified key curriculum changes. The pilot work in Spain helped me to refine the interview process and explore practitioners and pupils' perceptions of science. The main research carried out in Scotland developed from the pilot work and involved interviews with teachers and pupils which highlighted important curriculum changes required in science education. The results from interviews helped to shed light on the third research question and I then developed a new science curriculum with other science teachers: two focus groups of teachers; three case studies teachers and two curriculum development teachers and implemented this new curriculum in first year science classes.

The following table shows the total number of interviews carried out and the participants involved.

**Table 3.1      The Participants Involved in the Research**

			Female	Male
Pilot (Spain)	Pupils	A group of 8 girls and individually:	8	
		5 humanities	3	2
		6 science	3	3
	Teachers	2 humanities	1	1
		2 science	1	1
Main Research (Scotland)	Pupils	9 humanities	4	5
		11 science	7	4
	Teachers	9 humanities	5	4
		11 science	5	6
	Focus group 1 teachers	1 humanities	1	
		2 science	1	1
	Focus group 2 teachers	1 humanities	1	
		1 science		1
	Case Studies teachers	3 science	2	1
	Curriculum development teachers	2 science	1	1

At the time of beginning the research, I was teaching science in a secondary school in Spain. This was a British school which taught the National curriculum of England and Wales to A level. The medium of instruction was in English and pupils sat examinations set by the Cambridge Examination Board. Although the school was located in Spain, the ethos and majority of staff reflected a private, British secondary school.

Research rarely progresses in a smooth, linear fashion and the research I have undertaken also took a different direction. A change in personal circumstances meant that I moved country and job after the first year of embarking on the research project. By the following year, I had returned to Scotland where I began to teach science and learning support in a comprehensive secondary school in central Scotland. This school, with an enrolment of just under one thousand pupils, has an intake of children from a wide variety of social and economic backgrounds.

The initial first year of research into science education gave me the experience of starting to carry out interviews and research the literature. This was a valuable opportunity as it allowed me to become involved in the research process, explore the issues and gather initial data from Spain which pointed to a need for change in science education. I used the experience gained in the Spanish setting to clarify what the research was trying to achieve through refinement of the research questions, an exploration of how that might be realised, fine-tuning the interview questions and gaining the skills necessary to analyse data and draw conclusions from it.

Although a comparative study of science education was beyond the remit of this research, further research could discuss differences in cultural expectations and traditions in both countries and compare the experience of science education for practitioners and pupils in Spain and Scotland.

The initial study in the first year of investigating science and gender was the pilot project for this research. This gave me the opportunity to try out different types of interviews with different combinations of pupils, pose a range of questions or invite reflective discussion on subject choices with groups of girls about to make such decisions. It also allowed for honing interview techniques, asking different pupils to participate in the study and practice recording and transcribing data.

Importantly, I am working as a feminist, reflective practitioner and this influences the approach to undertaking research which explores issues of gender. The uniqueness of this study lies in its use of feminist approaches towards carrying out the research, combined with my standpoint as a feminist educator. These emphasise a commitment to feminist praxis which aims to create a feminist pedagogy grounded in feminist values. This is characterised by being reflexive, open to change, challenging dualisms and employing democratic organisational practices (Stanley, 1990). It is from this standpoint that the approach to shedding light on the research questions developed.

Research into the scarcity of women in science and the self-exclusion from physics classes by girls has been investigated by science teachers working inside the system (Bennett, 2003) and feminist academics outside the system



(Harding, 1986) but the originality of this research lies in my role as feminist, scientist and teacher and being in the position of carrying out research and bringing about change to practice.

This chapter sets out to discuss the link between theory and methods used in feminist approaches to research. It also looks at the question of ethics, which is particularly important given that the research involves young people. The chapter then has five main sections: a discussion of what is meant by feminist, reflective practice; the pilot research, the main research and the limitations of carrying out qualitative research and the matter of ethics.

The first part will concentrate on my perspectives towards research as a reflective, feminist practitioner and how this standpoint makes the study unique through being able to investigate and contribute findings to help improve science education by making it more inclusive. Then the issue of feminist epistemology will be considered, since the adoption of a feminist research paradigm has implications for methodology. Feminist writers such as Keller (1996) and Harding (1991) have challenged traditional knowledge systems, especially that of modernist science which assumes that there are unchanging truths based on secure fundamentals, and these have influenced this research in showing that alternatives are both possible and desirable:

*“feminists can bring a whole new range of sensitivities,  
leading to an equally new consciousness of the  
potentialities lying latent in the scientific project”  
(Keller, 1996, p.39).*

In the second section, the initial study which formed the pilot work for the research will be discussed. This addresses how the pilot research sample was chosen, the questions asked and methodological issues. The pilot research allowed for greater reflection on the aims of the research and the following part shows how the title and research questions were revised in the light of interviews and reflection on feminist literature and epistemology in order to carry out the main research.

The main research is then discussed in the third section which reflects on questions of methodology, looking firstly at the research questions and how

these were used to inform the methods adopted. The research questions provide a basis for forming interview questions and each question used in the interview is related back to the original research questions. In the light of this background, the theoretical framework is then linked to the methods used. The methods undertaken will be considered in terms of why they are thought to be the most appropriate and why alternative approaches were rejected. A discussion of research methods takes each research question in turn and shows how the research was realised in practice. Here, a justification of the type of interviews adopted and why it was deemed to be appropriate will be discussed as well as an outline of the collection of data.

I then move on to the exploration of the third research question of how the science curriculum, informed by a feminist perspective, would look, beginning with the contribution of focus groups then case studies teachers and curriculum development teachers towards developing a new science curriculum. The resulting topics chosen for implementation in classes are outlined to show how the approach taken towards teaching in science could be changed.

Finally, the limitations of this research project are discussed in terms of the number of participants and generalisation of the outcomes. The ethics involved must also be considered and ensured in any research project and I explore the ethics questions which arise in this particular study in the final section of the chapter.

## **Reflective Practice**

The research questions arose from my perspectives as a feminist, science teacher, and it is important to place my own experiences within the research questions. I enjoyed physical science subjects at school and found them interesting and challenging. The idea of there being a right answer was appealing, and I found that I was successful in learning, understanding and being examined in the topics covered. When the time came to choose subjects for further study, the physical sciences, chemistry and physics were my natural choices; a factor which I felt should be explored in this study, since these subjects are not the obvious choices for many pupils at this level.

Over the years I have given the matter some consideration in trying to understand why some pupils are more attracted to one subject over another and what mechanisms and experiences are involved which leads some pupils to opt for certain subjects. I was aware that many girls had opted for humanities subjects and did not want to continue with science. They did not see the relevance of practical work and did not find the topics interesting or useful. In contrast, they liked the opportunities for expression and creativity which they felt were offered by the arts and languages departments.

My own view of the humanities was that they did not offer such a range of career possibilities as science subjects did. They seemed to require a copious amount of writing and giving one's opinion on a theme, without clear-cut answers or discrete boundaries. Again, it was a puzzle to me that some pupils would opt for subjects that entailed composing long essays and analysing literature to search for its symbolism and meaning, whereas the sciences appeared to provide succinct, precise explanations for phenomena in the world around us.

I felt that studying the sciences could lead to a wider range of job options and studies, and I was encouraged to pursue this field by teachers, both male and female. My family also felt that the benefits from a career in science would be greater than those from other disciplines and approved of my choices. I also enjoyed being associated with the physical sciences which were widely recognised as high status subjects in the curriculum.

In the mid 1970s, there was a feeling that it was time for change and the introduction of the Sex Discrimination Act (Home Office 1975) and programmes to encourage girls into science came into practice. It seemed that more girls would be following a science career and that having solved the liberal feminist demands of access, changes in the law and in society would lead to greater equality.

However, after over twenty years of working in science education and in spite of the many initiatives and efforts to encourage a science career there are still repeated patterns of very few girls going on to study physics. It seemed, and I almost accepted as the norm, that girls don't do physics, yet this continued to concern me. Curriculum research and development has as its essential characteristics that of questioning our teaching practices and of being committed to reflecting on these with a view to developing and improving practice (Stenhouse, 1975). My interest in the reasons for low numbers of girls in physics shaped the first two questions as I sought to explore this area further. How indeed were girls self-excluding from science and why did boys find it an attractive option? What was the role of teachers in this issue? How did they see science education? I wondered if other science teachers viewed this as a burning issue and what they thought could be done about it or were doing about it.

A break from teaching and a return to studies in gender and education which focused on feminist theories gave me another perspective to the issue and led to the articulation of the final research question. The third research question formed as I considered the first two. I reasoned that it was interesting to find out more about why the scarcity of women in science had not changed over the years and that this could be investigated with pupils and teachers. However, in order for the research to move the issue forward, I should then see how progress could be achieved through the adoption and implementation of feminist approaches. This would involve looking at the science curriculum and exploring alternatives to it with other interested, key individuals in the form of focus groups, case studies teachers and curriculum development teachers.

Further reading of feminist writers, such as Harding (1991) and Hughes (2001) on women and science led to a re-examination of the science

education which has developed in secondary science classes. The authors criticise the science which has emerged as embodying masculine values and incorporating gender bias.

The research I have carried out is not science research per se but that of secondary school science, and it was through consideration of feminist viewpoints on science and my personal involvement in the world of science teaching that the research questions formed. I was not only interested in exploring what processes are at work which attract or discourage pupils from taking science subjects, I also wanted to see how feminist theory might be incorporated into the science teaching that I was concerned with as a practitioner. My perspective as a feminist, science teacher is valuable in giving the view of both an insider, as reflective practitioner, and outsider, as a feminist with the ability to carry out research and change practice.

Feminist praxis relies on being in a position and having the ability to provide alternative practices through working within the system. Research into pupils and teachers' perspectives of science education has been undertaken by feminists from outside the system and non-feminist science teachers from inside, but I am working on it as a feminist scientist, insider and outsider. The next section discusses this in more detail.

## **Feminist Epistemology**

The main concern of this study is the question of why girls are opting for subjects other than science in large numbers and how we can change this. It is therefore concerned with gender issues. There are many different research paradigms but I considered that a feminist approach would be the most appropriate, given its commitment to improving women's lives through changing unfair practices.

The principles behind this study most closely resemble the main tenets of feminist praxis, research as action and practice, with a commitment to understanding the experiences of women, reflecting on the research process and being open to change in that process. As an approach to research it therefore seemed to be the most appropriate choice for this investigation.

Feminist research is about "putting the social construction of gender at the centre of the inquiry" (Lather, 1995, p. 294) and this is an important aspect to the study. This includes explicitness of the process, a clear demonstration of reflexivity, flexibility through reflection on practice and showing an awareness of feminist principles, especially with regards to power relations.

The necessity of personal involvement in the research process is an important part of feminist research, according to Stanley and Wise (1990). This is an acknowledgement that feminist research should involve the experiences of the researcher as well as the participant. This helps to redress the balance in the relationship between interviewer and interviewee which tends to be hierarchical in nature. This is particularly true in the case of a teacher interviewing pupils, since the pupils may feel vulnerable in that the interpretation of their responses depends on the standpoint of the researcher and the meanings and values they extract from the data.

Feminist critical praxis derives from experience and is rooted in practice, continually subject to revision through reflexivity, open to change and illuminates women's and men's multiple and different experiences (Weiner, 1994). It is concerned with finding connections between experience and understanding (Maynard, 1994) and in this case, bringing about change in the field of science education.

It is worth considering what these terms mean and the implication for this research. My interpretation of reflexivity is one where the researcher has to analyse not only the values and beliefs of the social system they are studying but also their own values and beliefs in carrying out the research. Being open to change relates to being creative in thinking about alternative possibilities and I have tried in this research to construct a new science curriculum and to think about different ways of making practice more inclusive. This involves employing democratic principles, including more pupil-led work. Through interviews with pupils and teachers, consisting of approximately equal numbers of men and women, I explored the different experiences of science education which people have had and how this influences their perceptions of science.

Feminist literature points to the way schooling is gendered and the way science in particular has become a high status subject dominated by men (Harding (1991), Barton (1997) and Hughes (2001)). The challenge for feminist writers and practitioners is to contest the masculinisation of science, as Arnot (2000) suggests.

This is articulated by Volman, Eck and Dam (1995) who propose how this might be carried out:

*“Research on gender and education should not be limited to the investigation of statistical correlations between school and characteristics and pupil outcomes, but should also study the mechanisms and processes that mediate between these factors.”*

*(Volman, Eck and Dam, 1995, p. 286)*

It was with this intention of exploring the ways in which science education has come to embody masculine values that I set out to investigate the issues involved in this area. The mechanisms by which this occurs are explored through the interview questions with pupils and teachers.

As stated earlier, the third research question is one which is more complex in terms of obtaining data by interview or statistics alone. The research questions ask what science education would look like from a feminist

perspective and what it contributes to the current debate on gender and science by using focus groups and case studies teachers to explore how the principles of feminist theory can be translated into a classroom situation.

In reflecting on a new curriculum, I felt that the experience I have gained in my present post as a teacher of science and learning support was useful in that I work with colleagues to differentiate the science syllabus for pupils with additional support needs. My role is to look at the science curriculum with another science teacher and change the emphasis, materials and presentation to suit the needs of the pupils. In order to do this, we take the topics studied at this age level and develop appropriate and relevant materials in curriculum development sessions. In the classes I teach I have explored alternative ideas and explanations for phenomena with my pupils. In this way, I have incorporated feminist theories in practice, such as questioning the role of science, creating more democratic practices, in terms of pupil-led investigation, and encouraging more pupil participation in the lesson.

There are examples of research which incorporates feminist principles in science classes (see for example Barton (1997), Hughes (2001) and Hoffmann (2002)) which have been successful in offering alternative approaches to science teaching. The research I have carried out furthers this work by offering a new approach to teaching science classes in the early years of secondary level schooling and the following section shows how the pilot research was carried out and initiated the research process.



## **The Pilot Research**

As has been stated, the pilot work began when I was teaching at a British school in Spain. My concerns as a physics teacher for the low participation of girls in physics grew from the repeated experience of seeing girls opt for subjects other than physics when offered alternative subject choices. It also seemed interesting to me that boys apparently did not feel that physics was a subject they should avoid, even if they had not been particularly successful in studying the course. Both of these observations left a feeling that my role was in some way contributing to this perpetuation and this feeling deepened through reading feminist critiques of science (Harding, 1991; Keller, 1996), which identified science as a predominantly masculine domain.

The contribution of the pilot work was to assess the practical feasibility of the research plans, test procedures and to see whether the analysis of results could produce the kinds of results required to investigate the research topic. It would be useful to look at the pilot research in sections, beginning with the original research questions, then a discussion of the research methodology in relation to the objectives of the study, including how data were obtained and how it worked out in practice then finally how the pilot research led to changes for the main research.

## **The Pilot Research Questions**

The central purpose of the pilot research was to explore the themes of the low participation of women in science by investigating three research questions. These asked why girls leave physical sciences, why boys opt for these subjects, and how science education could be made to be more inclusive using insights from feminist writing.

The title originally read “Girls and Physical Sciences: a study of pupils’ perceptions of physical science at secondary school level” and the intention was to focus mainly on girls’ views on science. However, liberal feminist approaches (Garratt, 1986; Reiss, 2000) tend to perceive self-exclusion from physics as a ‘girls’ problem’. These approaches avoid a critique of science or education and it became clear that I could not study the girls’ experience

in isolation from that of the boys and those imparting the subjects - the teachers. The participation of a wider range of participants, I felt, would help to shed light on the question of gender and science and offer a more extensive picture of the issues.

The idea was to use the information from interviews with pupils and teachers, effectively that of the first and second research questions, together with feminist research on science to develop a small part of an alternative science curriculum which could be implemented in schools.

### **The Pilot Research Methodology**

Informed by feminist research (Stanley and Wise, 1990; Weiner, 1994) which has tended to use interviews as a means to explore matters, it seemed that the most appropriate way to examine perceptions was to interview pupils in order to bring out their viewpoints and feelings towards the subjects.

I considered that a group interview would be the best starting point as the interaction of the group could bring to light information, insights and specific issues I could follow. Lather (1995) writes that group interviews: “provide tremendous potential for deeper probing and reciprocally educative encounter” (Lather, 1995, p.299) and it was this rich source of data which I wanted to explore initially.

The research process began with a group interview with eight girls who had just made their course choices for post-compulsory level subjects and were about to enter year 12. I had taught chemistry and physics to the girls and wanted to know more about their choices of subjects for A level. At that point, I was interested in getting a general picture of trends and their perceptions of science education. I formulated questions which asked the participants about the subjects they were going to take for A level, what their reasons were for taking them, and if they thought science was important.

I approached the girls in my class and asked for volunteers to debate the issue of girls and physics. Eight girls came forward and wanted to be

interviewed together. This made for a lively debate although it was dominated by a few voices whilst others remained silent or said very little. The role of the group interviewer tends to be one of mediator, rather than interviewer (Punch, 1998) since the debate, unless highly structured, continues with its own dynamics.

However, I was encouraged by the positive response to the discussion and enthusiasm for talking about attitudes towards science, which were seldom consulted. I also felt that the debate had reflected a feminist approach to research in giving 'voice' to the girls and helping to redress power imbalances through facilitating open discussion. Eight participants made for an interesting conversation, though I found that transcribing from the tape was difficult in terms of distinguishing who was talking and understanding what was said when a few girls talked at the same time.

On reflection, although the group interview had been useful in terms of highlighting various emerging themes, I then decided that it would be better if pupils were interviewed in pairs or in groups of no more than three in order to explore the issues in greater depth. I also felt that I should include the viewpoints of boys as well, since their opinions would help to illuminate the question of why boys felt drawn to physical science subjects. I then interviewed a further 11 pupils, consisting of five boys and six girls, either individually, in pairs or groups of three. The participants' involvement was on a voluntary basis, and they chose their preferred interview partners which were same sex groupings.

Using information from the outcomes, I refined the questions to be asked in order to probe how their subject options were influenced by career choices, why they had chosen certain subjects, and why they thought science was important in our lives. Responses were categorised to produce themes, and these were explored with the next interview participants.

The research was an exploratory and iterative process where I used the responses from one interview to inform the questions for the next in order to ask questions which pupils could reasonably answer and which probed the issue with sufficient depth. Carrying out a series of interviews and transcribing them was a valuable exercise in both gaining experience of

carrying out research and reflecting on the implications of what had been said.

Conversations with colleagues in the teaching staff revealed interesting perspectives on the issue of girls and physics, and I decided that it would be informative to interview two teachers from the sciences and two from humanities in order to shed light on the research questions. The outcomes from these interviews showed how teachers reflected on their subjects and this led to the realisation that teachers were key participants in changing the science taught in schools and that their views were equally as important as those of the pupils.

Feminist critiques of science and science education emphasise the need not only for research and comment but also a commitment to change and to improve women's lives, a feminist praxis (Stanley, 1990). With this premise, I felt that an exploration of perceptions of science with teachers and pupils through interview did not go far enough in terms of feminist research but that a new practice was called for to change the situation. Whilst the results from interviews with teachers and pupils was illuminating in finding out about why girls were choosing subjects other than science, I also saw that this data should be used to help create a more inclusive science curriculum.

I was in the privileged position of being a science teacher working as an insider in the education system and also an outsider, researching as a feminist. The uniqueness of this research arises from my perspective as practitioner informed by feminist theory and with the opportunity of changing the science I was teaching.

By the end of the first year of carrying out the research, I was able to use the experience gained through investigating the research questions to structure the main research, find the most appropriate methods used to obtain data, and link these with the theoretical framework. The pilot research acted to formulate questions, give me the experience of interviewing a variety of pupils and teachers and consider how feminist approaches could help to inform the third research question.

## **Changes to the Main Research Resulting from the Pilot Work**

After carrying out the pilot work I remained committed to searching for answers as to why there were so few women in science; why the scientific establishment was so male dominated and how the data from the pilot research could be used to create a more gender inclusive curriculum.

In terms of changes to the main research, the pilot work showed that a larger number of pupils and teachers would give a more diverse range of data. However the project is necessarily limited in terms of how many interviews could feasibly be carried out and then analysed in the time period. Given the emphasis which feminist research places on depth and quality of data over quantity, the number of twenty teachers and the same number of pupils was reached as a reasonable number to deal with over the period of the following year.

In order to shed light on the final research question (that of how a feminist perspective could contribute towards a new science curriculum) groups of interested teachers, whom I had informal chats with on the issues, were brought together to discuss their views with a focus on changes in science education. This helped to inform the third research question and point to ways forward with curriculum change and evaluation.

In addition, I wanted to speak with practitioners who had an interest in changing science education and some experience of developing alternative approaches to learning about science. I identified different groups of key individuals, all science teachers, whose experience contributed to finding a different way of approaching science teaching.

To summarise, the pilot research was invaluable in the following areas: sharpening research techniques concerned with interviewing; pointing to the numbers of pupils who should be consulted and showing that the involvement of teachers was essential to develop the research. These both helped to shed light on the first and second research questions and pointed to the way in which the third research question could be developed. In addition, the pilot work also highlighted the additional need for focus groups of teachers, case studies teachers and curriculum development

teachers to help inform the third research question relating to a new science curriculum.

The experience of working through the initial study helped to shape the research which began with a consideration of the research questions. It would be useful to look now at how the research questions were investigated through a discussion of methodology.

## **Methodology**

Methodology refers to the theoretical framework employed in the research and the link between theory and methods. It involves a reflection on the methods employed in the light of the theory and the research aims of the study. Hence, it shows the link between theory, research methods and process.

Since I am interested in people's views, I considered that a qualitative approach through interviews would be the best method of gathering data. The use of interviews tends to be favoured by feminist researchers as a means of shedding light on the research questions through its emphasis on exploration of experiences and feelings. As Maynard (1994) suggests, focusing more on the experiences of the interviewees is seen as being more in keeping with feminist views of research, and "appropriate to the kinds of knowledge that feminists wished to make available" (Maynard, 1994, p.11). On the other hand, quantitative research was initially criticised by feminists as distorting meanings through emphasis on specific experiences.

There is a fundamental difference between qualitative and quantitative approaches to research and this lies in the concept of what is meant by knowledge, showing itself in the methods used, and in the approach to analysis. Quantitative approaches tend to ask "how much?" or "how many?" whilst qualitative asks "what is meant by ...?" Hence, though the two may be complementary, each providing a different type of data, the knowledge produced is distinct.

When thought of in terms of variables and involving the use of questionnaires or surveys, quantitative research, which searches for causal

relationships, could have given a substantial amount of numerical data about science education. Had the research questions asked how pupils rated science, a survey could have provided that information and included larger numbers of participants. Quantitative approaches also have the feature of giving anonymity to the participants, which can be an advantage, particularly for sensitive areas, such as domestic violence (Jayaratne and Stewart (1995)).

Denzin and Lincoln (1994) describe the attributes of qualitative approaches thus:

*“Qualitative researchers study things in their natural settings, attempting to make sense of, or interpret phenomena in terms of the meanings people bring to them.” (Denzin and Lincoln, 1994, p.2).*

In the research I have carried out, I made use of government statistics to demonstrate that many pupils, particularly girls, are leaving physics at post-compulsory level. To that extent, I have been able to use this quantitative data in the form of statistics from which to begin the research with an exploration of the perceptions of physics, a strategy put forward by Jayaratne and Stewart (1995).

Hence, the trends in uptake of physical sciences, as shown by the figures which demonstrate “how many?” or “how much?”, can then be used to move towards the types of questions asked in qualitative research such as “how does this happen?” and “what is meant by this?”. It is the concept of the knowledge which is sought which distinguishes the different approaches.

The type of research which I have carried out involves the collection of data from personal experience, interview and observation that describe moments and meanings in peoples’ lives. This study is concerned with questions of “why” and “what mechanisms” which need to be explored through debate and analysis. This would be difficult to achieve using questionnaires, which tend to restrict responses to some pre-conceived categories and only allow for limited discussion. Instead, a qualitative approach was adopted to allow

for layers of meaning to be probed and perspectives identified. The way in which this was carried out is discussed in the following section.

## **Research Methods**

A move back to Scotland after completing the pilot research meant time was needed to settle into another science teaching post, make contacts with other teachers in the field, and develop relationships with staff and pupils at my new school, a mixed comprehensive in central Scotland. However, the pilot research was important in learning more about the research process, refining interview skills, analysing data, and moving the research process forward in terms of creating a more inclusive science curriculum.

The main research involved discussion with twenty pupils and twenty teachers in interviews to explore their understandings and experiences of science education. Debate with practitioners led to key curriculum changes and concepts being identified through which we developed a new science curriculum.

## **Choice of Participants**

The study involved pupils and teachers in Scotland whom I had been working with as a teacher in the school, and other colleagues. After gaining permission from the head of schools in the region to ask the pupils and teachers about their views, I then spoke with the pupils and teachers directly and asked them if they would be interested in sharing their thoughts on education with me. By using a sample of pupils and teachers, who had made academic choices about their futures, but all working within a secondary school system, I could triangulate (Denzin, 1978) findings from multiple data sets, in this case, the transcripts from interviews.

In terms of pupils, I asked fifth and sixth year pupils (ages 16-18) if they would like to participate in a research project on pupils and teachers' views of different school subjects. Pupils who volunteered were then invited to be interviewed in pairs or individually. If it was possible, I tried to pair or



group pupils to include one from humanities and one from science, to contrast experiences. A sample of a pupil interview with three girls, two humanities and one science, is given in Appendix II.

The analysis concentrated on pulling out the meanings pupils and teachers attach to science and science education. In this sense, as with much qualitative research, a process of ‘analytic induction’ was carried out in “the systematic examination of similarities between cases to develop concepts or ideas” (Punch, 1998, p. 201-202).

The teachers were chosen because of their interest in the subject and their passion for the work they do. They were all dedicated teachers who felt strongly about their particular fields and in what they were trying to achieve. The teachers had all reflected on their teaching styles and the learning styles of their pupils and tried within their lessons to utilise a variety of different ways of presenting topics in order to address the needs of their pupils. The teachers were identified by me as showing an interest in the issue of the low representation of girls in physics through informal discussion and staff room conversation.

Their inclusion in the research was on a voluntary basis and the interviews were carried out during or after the school day. Although it may have been more conducive to conversation to have carried the interviews out in a neutral setting, the teachers generally did not seem reticent about expressing their views and reflecting critically on the education system and the syllabus they were given to deliver. I selected participants from both humanities and sciences in order to compare outcomes. A sample of a teacher interview is attached in Appendix III.

In addition, I also explored the third research question with science and humanities teachers working within the education system on alternative approaches to science teaching. These formed the focus groups and an example of an interview with a focus group is given in Appendix IV.

There were two different focus groups involved. The first consisted of two science teachers, one female biology teacher and one male physics teacher. The third participant was a female modern studies teacher. All had been

interviewed as part of the teacher's interviews and had shown a particular interest in the research.

The second focus group involved an ex-colleague who was working on a programme to break down the science / humanities dichotomy through a cross-curricular approach to teaching science topics. The participants were a male science teacher and a female history teacher. They taught at the school in Spain and were trying to change the curriculum by exploring alternative approaches to science classes, that would give pupils a different experience of learning science. Again, this information was useful in helping to shed light on the third research question.

In interviewing three case studies teachers, whom colleagues had identified to me when I had spoken to them about the research, I was able to tap into people's experiences of science education which was different from mainstream classes. All of these participants were science teachers. The first had a different experience of learning physical science from the traditional approach used in secondary science education, whilst the second was her physics teacher in that school and the third, an engineering lecturer involved in various initiatives to encourage girls into science and engineering at university level (a transcript of this interview is attached in Appendix V).

The curriculum development teachers were colleagues with whom I was working in my role as a teacher of learning support. One was a male physics teacher, the other, a female chemistry teacher. I worked alongside these teachers in order to support some pupils with learning difficulties in their classes. The teachers were keen participants in changing the science curriculum as they were keenly aware of its limitations and the barriers it created for pupils, many of them girls.

As far as the teachers are concerned, they represented a humanities or science background. As such, their responses reflected their experiences from these perspectives. Science teachers and science pupils were included in the study because they were seen by me as being the key towards offering an insight into their perceptions of science education and in bringing change to this field.

Interviews involving over forty participants generate a large amount of information which has to be processed. The data produced are rich in quality. They contain valuable and pertinent observations and interpretations of science education which help to shed light on the research questions. However, in order to bring some meaning to the study and to relate the outcomes to the research questions, the first stage of the analysis necessarily involves reducing that amount to manageable categories.

### **The Framework for Analysis**

The framework for analysis of qualitative data outlined by Miles and Huberman (1994) offered the clearest process for analysis of data produced and seemed to be the most appropriate for this case, given the type of data involved, that of taped interviews. Miles and Huberman's framework for qualitative data analysis suggests that data be analysed through a process of collection, reduction, display and conclusion. This staged process takes the study through different phases in a logical and cyclical progression.

The collection of data was in the form of taped interviews. I recorded each interview with pupils and teachers on a tape recorder then transcribed the interview tapes. The interviews were carried out in the school where I taught, with the exception of four teachers and four pupils from another school which were carried out at my home.

The reduction of data is part of the process of analysing the data. It is not one which is carried out at a particular time and then ends. It is a continuous process which the researcher embarks on from the beginning of the research. It involves summarising the data at the start of data collection, in this case as I transcribed the tapes, making notes of the broad themes covered in the interview. Then whilst coding the data and finding themes and patterns, data is also reduced. In the final stages of developing concepts, the data is also reduced.

Though the reduction of data is a process which is more identifiable with quantitative approaches in reducing the figures to manageable trends or concepts, it is also applicable to qualitative analysis, provided that important

information and the context of the data gathered is not lost (Miles and Huberman, 1994).

The display of data helps to organise and arrange information so that the large amount of information, typical of qualitative analysis, can be made more manageable and help in the analysis of the data. Another stage in the process is that of drawing conclusions from the data. Again, this is not the final part of the process, although it draws together and verifies information. Meanings are pulled out and brought together whilst reduction and display of data are occurring.

Hence, the process of analysing data, according to Miles and Huberman's (1994) framework for analysis of qualitative data, is a continuous one where outcomes from initial interviews are used to inform subsequent interviews. In this study, I used the results from the group interviews and initial pupil and teacher interviews to feed into further interviews with other participants. Results from these interviews then informed subsequent interviews with focus groups, case studies and curriculum development teachers. This means that the process is an iterative one; building upon what has been established and giving importance to each stage in its contribution towards the progress of the research.

The authors highlight the problems of inference from small scale projects and suggest that different data and different methods can help with triangulation (Denzin, 1978) of results. In this case, I felt that statistics from national examinations, together with the range of data from interviews with pupils and teachers, the different case studies, the use of focus groups and curriculum development teachers together with observations of classes helped to reduce errors in inferences and made the results more reliable than one using only one type of data.

Although there are commercially produced computer programmes (such as NUD•IST) for analytic approaches, through which large amounts of qualitative data can be coded, I felt that in this case, the numbers of participants were small enough to allow me to analyse the transcripts by going through each in turn then looking for themes.

The data collected from a qualitative approach is full of subtleties and inferences, and it seemed that a computer programme would not be appropriate in this case as some of that information and richness would be lost in the process of reduction. Programmes designed for analysis of data search for repeated phrases or key terms and group these under headings to produce manageable quantities of data. However, I did not want the results which I obtained from the interviews to be isolated from their context, losing the depth and richness of meaning in the process.

Familiarity with the data helps to shape the conclusions drawn, and I felt that more direct contact with the transcripts would benefit the research in terms of giving a more accurate picture of the issues being investigated. In this case, the full transcripts were hung on a wall and I highlighted those words or phrases which indicated particular themes using different coloured pencils.

By using this process of coding (as given in Punch (1998)) where tags are used to show up pieces of data in the form of phrases or words, then giving these pieces of data labels, I was able to pattern codes by pulling the codes into smaller, concise units. There were a variety of categories to which the transcripts from interviews pointed. When these different themes and ideas were drawn together, a picture emerged of patterns in the participants' responses.

The research methods employed are the techniques used to gather evidence. As this study represents a qualitative investigation which is to do with finding meanings, understandings and perspectives, the methods used could include observation and participant observation as well as interview. In this case, some classroom observation did take place in implementing a new science curriculum in order to see the reaction of the pupils to alternative approaches to science teaching. I was also able to observe pupil presentations of project work in the form of written and slide presentations in order to evaluate how successful this had been.

However, the main investigation involved exploring the feelings, viewpoints and experiences of the participants, and this information is more readily collected from conversation. In this way, I decided to carry out semi-

structured interviews (Stanley, 1990) which would have particular questions on which to focus so that the participants might stay on the theme but with enough flexibility to allow for an exploration of the issues.

An open interview in which the conversation is not directed in a particular path might have meant that I did not get the responses to the issues I wanted to discuss. Conversely, a set of questions which had to be answered like a questionnaire would have not been conducive to an exploration of viewpoints, so the semi-structured interview was deemed to be the best compromise.

The study is involved with looking at how meanings are negotiated, how roles are developed, and what processes are involved in choosing subjects in the curriculum. The questions asked in interview therefore had to bring out this type of data. These ask about the respondents' perspectives of the subjects they study or teach: what they found interesting about the subject; how they thought it was useful; why they thought that some people are more attracted to some subjects than others; how it enriches our lives and how the subject might be made more attractive. The questions asked in interviews, and the information sought, together with the prompts used are attached in Appendix I.

The questions were directed at all participants, pupils and teachers, and if that respondent came from a humanities background, the answer would obviously reflect the participants' view of that area. This was designed to shed light on pupils and teachers' perceptions of other subjects and to help illuminate the reasons why some subjects were seen as more attractive than the physical sciences. The questions employed and the reasons for their inclusion are discussed in more detail in the following section.

### **The Interview Questions**

The research questions inform the questions asked in the interviews. Each research question was taken in turn thereby helping to form interview questions, which could be posed to both pupils and teachers, so that comparisons could be made.

The first two research questions address the issue of perceptions of science and other subjects in the curriculum by pupils and teachers. They ask:

*What are the mechanisms which both inhibit girls from choosing physics and encourage boys to pursue this subject at post-compulsory level?*

*How do teachers perceive and relate science as a subject in the curriculum?*

These were questions which I hoped to explore with the pupils and teachers through the interviews. The first interview question asked what pupils and teachers find interesting about the subject they study or teach and encouraged them to discuss what they saw as attractive features of the subject. The interview question was there to open up the conversation and help to focus on the reasons why pupils and practitioners make subject choices and what draws them to a particular topic.

The second interview question was designed to open up the discussion more and allow pupils and teachers to express their views on specific skills and parts of the curriculum which they felt was useful. I used prompts to encourage an exploration of this area and to see what attracted the participants to some subjects over others.

The third interview question tried to get the pupils and teachers' general perspectives of the sciences and humanities subjects. In this way I discussed with them the contribution made by these areas to our lives. This indicated why they felt the area they had chosen to study or teach was important to their lives and to society generally.

The aim of the fourth interview question was to explore the issues of values and identity in the curriculum by looking at participants' perceptions of the way some subjects are seen as being more attractive than others, why they thought it happens, and what their explanations for it were. This was included to help illuminate the research questions by talking about what leads to more girls in the humanities and more boys in sciences, particularly physical sciences.

The last interview question moved into the area of how we could make the particular subject they were teaching or studying more attractive. Their comments were useful in contributing to how science might be made more attractive and inclusive by incorporating different approaches or in using some of the styles of learning and teaching which go on in the humanities.

Their comments helped to focus on the third research question which asks:

*How could a feminist perspective contribute towards a new science curriculum in order to change the approach to teaching physics?*

The reasoning behind asking about participants' attitudes towards other subjects was that these might offer some ideas of how science education could be changed to become more inclusive for all pupils.

The third research question attempts to further the aims of feminist research and in particular feminist praxis outlined by Stanley (1990) in not only researching gender issues but also by helping to make a positive contribution to changing unjust practices. The question is not one which could be translated directly into an interview question as it is too complex an issue to try and answer in a short interview. Instead, I used information from a combination of the final interview question and feminist theory then carried out additional interviews with focus groups, case studies and curriculum development teachers to help inform the third research question.

### **The Third Research Question**

The third research question asked how a feminist perspective could be related to a new science curriculum and by using the outcomes from interviews with pupils and teachers, informed by feminist praxis, I initiated further discussions with key practitioners which led to the development of a new approach to science teaching. At the same time as carrying out the main research interviews with pupils and practitioners and in general conversation with colleagues, I identified teachers who had shown a particular interest in and enthusiasm for the reform of school science. I met with these teachers to see how their perceptions and experiences of science



teaching might further the study by creating a more inclusive science education for all pupils. This took the form of discussions with two different focus groups of teachers, three case studies teachers and two science curriculum development teachers to create a new science curriculum for implementation in first and second year science classes.

Outcomes from all of these interviews gave a new dimension to the study in terms of helping to shed light on the third research question and showed that there are ways in which different approaches can be successful as well as being more inclusive. A discussion of how each of the groups contributed to developing a more inclusive curriculum is outlined in the following sections.

### **The Use of Focus Groups**

One of the most important stages of the research process was the involvement of focus groups in the discussion of the third research question which asked what science education would look like from a feminist perspective. The first focus group consisted of science and humanities teachers who had been interviewed by me individually and whom I identified as participants who had shown an enthusiasm for their subject. In the interviews, they had shown that they wanted to speak more about the area around the last interview question, that of how we can make our subject more attractive to pupils. It was with this question that I brought the focus group together to start off the discussion and the result was a transcript rich in data and informative in terms of shedding light on the third research question (an example of a transcript from a focus group interview is given in Appendix IV).

The interview began by asking how we could make science more attractive. My role was to prompt and keep the interview focused on this issue. The prompts were used by me to ask for clarification of statements made and to reflect or re-state a comment in order to verify meanings. The absence of pre-determined questions meant that the debate was more dynamic in openly exploring how we could move forward in making science more inclusive, an

approach to investigation extensively employed in feminist research practice (Maynard, 1994).

The use of focus groups is one widely used in feminist research since the interaction of participants over a topic which they feel passionate about is conducive to discovering more about thoughts and opinions. As Punch (1998) states:

*“Well facilitated group interaction can assist in bringing to the surface aspects of a situation which might not otherwise be exposed. The group situation can also stimulate people in making explicit their views, perceptions, motives and reasons. This makes group interviews an attractive data gathering option when research is trying to probe those aspects of people’s behaviour. They are inexpensive, data-rich, flexible, stimulating, recall-aiding, cumulative and elaborative”*  
(Punch, 1998, p. 177).

The second of the focus groups consisted of ex-colleagues who were working on cross-curricular activities for teaching about aspects of science. The teachers decided to teach about the renaissance through the history and science of the period by combining both stories and experiments from the point of view of the ordinary people and scientists who were involved. I wanted to include their experiences in the body of data from interviews as they had expressly communicated that the purpose of their work was to break down the science / humanities dichotomy, which they felt created gender divisions and unnecessary barriers to learning. Again, the use of open interview with prompts to clarify and assist continuity, beginning with the notion of how we could make science more attractive, was put to the participants who reflected on their experiences of teaching through cross-curricular activities.

## **The Use of Case Studies**

In addition to the input from the focus groups, I also felt that it would be interesting and useful to interview teachers who had taught, and pupils who had studied in the context of a different approach to science education. These formed a group of case studies teachers who were able to offer a detailed picture of their experiences in learning or teaching physical sciences. The object of carrying out case studies is to gain an understanding of the matter in question and its complexity within a particular context or natural setting (Punch, 1998). It has a “holistic focus” (Punch, 1998, p.150) which aims to maintain a comprehensive conception of the research issues.

Contact with the participants for the case studies came through the teachers’ interviews. This use of contacts through other participants is referred to as snowball sampling (Salganik and Heckathorn, 2004), where one participant informs the researcher about another individual who would be able to participate in the research, thus building up the numbers of those involved in the research.

One of the humanities teachers (female humanities teacher 10) told me about an ex-colleague who had taught physics to a girls’ class within a co-educational comprehensive school, also in central Scotland, and had tried to change the approach to teaching this class, primarily to encourage more girls to take physics. I was able to interview the teacher to see how his approach was different and how it had affected the perspectives of his pupils towards the physical sciences. The humanities teacher was also in touch with one of the pupils from that class, and I was able to interview this participant in order to find out her feelings about the class.

The third case studies teacher involved became known to me through an educational advisor I have worked with in Scotland. This participant taught aeronautical engineering at university level and had been seconded for two years to create initiatives to encourage more pupils into science. Her experiences were valuable in adding further information to the data from the participants and illustrating how the third research question could be developed. The transcript of this interview is attached in Appendix V.

Interviewing the case studies teachers was useful in showing that there are different approaches which have been carried out in various schools and these have met with some success. Their understandings of the way science can be presented at secondary school level help to affirm that change in science education is possible and that there are alternatives to the 'science as usual' approach.

### **The Curriculum Development Teachers**

The final stage in creating a new science curriculum came from discussion with the curriculum development teachers. I had taught with these two teachers at different stages in my capacity as a science and support for learning teacher in the school and helped the pupils in their classes with theory and practical work during lessons. Whilst working with these teachers, I observed the classes and took notes to record activities as they happened. I felt that intervention in science education should come in the early years of secondary education, rather than at post-16 level, and my involvement in learning support with first year classes placed me in the advantageous position of being able to work on creating a more inclusive curriculum with the pupils I was also helping to support in terms of learning.

We worked on two (of seven) themes from the first year syllabus, those of energy and water, with a view to making science more inclusive and bringing in debate on the costs and benefits of science and technology. The worksheets which the school had available were uninspiring to many staff and pupils, though these were only supposed to act as guidelines and not as texts to be followed. However, many teachers followed these worksheets which took pupils through a series of practical work, much of which was predictable and which the pupils had already covered in primary school.

The physics teacher, whom I taught with, also followed these booklets to a certain extent but was aware of how narrow and restrictive they were in their approach to teaching science. I felt that pupils should have a wider understanding of science and that the learning experience should begin with the pupil's standpoint.

In addition to supporting this mainstream class, I also taught a class of first year pupils (ages 12-13) topics from the first year syllabus. These pupils were less able academically but followed the same topic range as all other pupils, though using differentiated materials. This meant that, alongside other colleagues from the science department, I developed a curriculum which was accessible, interesting and challenging for less able pupils, yet which covered the knowledge and skills required. This aspect of my teaching gave me the experience of looking at the science syllabus from a different perspective and allowed the development of a part of the science curriculum which was more socially relevant and inclusive.

Feminist writers such as Rosser (1990) and Barr and Birke (1997) offer guidelines as to how feminist practitioners can change the way in which science is taught. These recommend using an inter-disciplinary perspective, promoting an awareness that all knowledge is socially constructed and that culture reproduces itself in the classroom. Being conscious of this can be used to our advantage in teaching a more inclusive science education. Rosser (1990) states:

*“Insuring science and technology are considered in their social context with assessment of their benefits for the environment and human beings maybe the most important change that can be made in science teaching, for all people, both male and female” (Rosser, 1990, p. 72).*

This was an aspect of change which was possible within the confines of the science programme and the circumstances in which I was involved in the class. However, I wanted to further the research by Rosser (1990) and Barr and Birke (1997) by extending this to change not only what we teach but how we teach it. It was with this premise that I looked at the current syllabus to see how this might be realised in practice. In working with two different colleagues, one a male physics teacher, the other a female chemistry teacher, in two different classes, we developed two topics, that of energy and water, which offered the opportunity of trying out a different approach to the way they had been presented. I kept a diary of classroom observations during the implementation of these topics in class in order to

record reactions to the work and my own feelings about how the lessons had been received. The next sections outline how each topic was addressed.

## **Energy**

In the school where I teach, the topic of energy is one which is traditionally taught from the viewpoint of there being six different types of energy, each being inter-convertible and identifying which energy changes take place when an event happens. Practical work takes the form of looking at different types of energy and seeing how energy is conserved. The worksheets and assessment for the course rely on experience of the set experiments and outcomes from these with little room given to discussion of the wider issues.

The class was made up of a total of sixteen pupils, eight boys and eight girls. My colleague (a male physics teacher) and I were concerned that more global issues of the energy crisis and the way economic power is associated with greater energy resources was being omitted from a study of energy. I felt that a discussion of the costs and benefits of the energy which we in western cultures have at our disposal should be included.

Since these are important but complex issues, we began by asking pupils about some objects they owned or wanted to own which required energy to function and which they regarded as essential - something they would find it difficult to live without. By focusing on actual objects, we were able to look at some tangible connection between the pupil and the energy they personally use. In small, mixed groups, they then wrote down a list of these objects on posters and debated which items were not essential. The pupils then passed on these posters to other groups so that they could add their comments.

The posters helped to focus thoughts on the bigger picture of where our energy comes from and the global issues of the future of energy. Pupils debated why they thought that their particular object was essential or not at all important. The discussion then moved on to whether it was fair for the west to have great control of and access to the world's energy resources and how this has come to be.

At the end of the section on energy, pupils were asked to do an individual project on some aspect of energy. The project work was part of the school science syllabus for first year pupils and was restricted to one week out of a two year programme. Though many tended to focus on a particular energy source, how it originated and how it was used, some pupils chose to talk about the need to look at the options open to us in the future with the development of more efficient, alternative energies.

Evaluation of the topic was through informal discussion with small groups whilst they were writing the posters to see how they found this type of work. I was also able to look at the energy projects from some of the pupils to see how they had interpreted the task and how it had impacted on their ways of thinking about science. After implementation of this different approach to teaching, I interviewed my colleague to ask for his perceptions of how the lessons had been received by the pupils, what he felt were important outcomes from the lessons and whether the science education we had presented was more inclusive.

## **Water**

Again, this work was carried out in a first year secondary science class. The total number of pupils was sixteen, seven boys and nine girls. I worked with my colleague, a female, chemistry teacher, on looking at the topic of water to see how we could change the content and delivery in order to make it a more inclusive learning experience for the pupils.

Like energy, the topic of water had previously been covered from the standpoint of process and properties. Very little attention was paid to human involvement and the real world. Pupils were not asked to consider the social aspects of water. Instead, the programme of study was based on worksheets which led pupils through a series of steps: reading a short text, copying out a summary of that text, drawing out a table then following step by step instructions to carry out an experiment then finally writing a conclusion from the results obtained. The section dealt with the practicalities and mechanics of water, in dissolving, cleaning and obtaining drinking water, but none of the wider issues.

Pupils were already familiar with the processes of speeding up the dissolution process through heating and stirring. They were bored by the 'recipe book' type experiments of going through a process to see how some substances could be made to dissolve faster by breaking them up. This they already knew from life experience.

The work suggested on the subject of water by the topic books did not challenge the ideas of the pupils. As teachers, we felt that pupils should develop an awareness of the way our attitudes and conceptions of water are different from those of other people, especially those in developing countries. As a feminist science teacher, I felt that it was important that the gender issue should be brought to the forefront of the discussion to openly challenge the injustices involved in obtaining and maintaining a precious commodity such as water.

I began the lesson by introducing the topic of water as being one which will be the biggest issue to face us this century (from the UN website: <http://www.un.org/works/water>). I then asked pupils why they thought this was so. The pupils came up with the ideas of problems stemming from pollution, global warming and water scarcity.

Pupils were then shown a video of the MTV diary of a rap artist and United Nations ambassador Jay-Z, who outlined the problems which many people in the world have in obtaining safe, clean, drinking water. After watching the video, my colleague opened up a class discussion on water. She began with the pupils' own experience of using water, through themes of water on a global level and on to how many people have difficulty in accessing it, and the connection between girls' education and water in poorer countries.

Pupils were then asked to complete a small project in groups for presentation to the class. The project involved some of the problems of the world's water. As teachers, we felt that pupils should decide on the learning outcomes to help in redressing the power imbalance and in encouraging greater pupil involvement in the classroom activity – as proposed by a feminist approach (Stanley, 1990) to teaching. In terms of success criteria for measuring the outcomes of these projects, it was decided by the pupils



that peer assessment would be the best yardstick with which to measure whether they had achieved their learning outcomes.

They decided that there were five ways in which they could measure those criteria:

1. The project should identify the problems of water and have good, relevant facts.
2. Everyone should learn something new.
3. The audience would listen.
4. There would be a variety, e.g. words, pictures, effects.
5. The presenters would be well rehearsed.

These outcomes were made into a questionnaire so that pupils could comment on how well each others' presentations had addressed these outcomes.

Pupils then formed groups and investigated the topic through internet use to find out more about the global issues of water. There were three periods available in class time in which to work on the projects. On the third day these projects were presented to the class who commented on the presentation using the learning outcomes as a basis for evaluation.

The pupils also completed an evaluation form which I had prepared in order to evaluate the pupils' attitudes towards the project. The questionnaire which the pupils answered is given in Appendix VII and centres on what part of the project they had liked; whether they thought they learned more doing project work; how we could improve on this, and if they would like to do more project work. To finish off the project time and topic, we gave all the pupils a bottle of water and thanked them for their great efforts. Again, this was followed up with an interview with the curriculum development teacher.

In order to evaluate the success of the new science curriculum, I interviewed the two curriculum development teachers to have some understanding of how they felt the projects had worked out in practice. The discussions were

semi-structured, using three main questions and prompts which asked for clarification of points made. The questions focused on three issues: that of what they felt had worked best, how and in what way it had worked and whether they thought that the work that we had done helped to make science education more inclusive.

An example of the interview with the female chemistry teacher is included in the appendices, Appendix VI. The reasoning behind its inclusion was to look at the other teacher's perceptions together with my own reflections on how the research had been received in practice.

### **Limitations**

A small-scale qualitative research project has limitations in terms of the generalisation of data across different contexts. The research was restricted to a total of seventy one interview participants and the new curriculum was implemented in only two different classes. This necessarily limited range of work makes generalisation to other education systems and learning places problematic.

However, as Schofield (1993) points out, the merit of the research may lie in making the reasonable hypothesis that the research problem, science education in this case, is widespread. Certainly the national statistics on the uptake of physics show that pupils are increasingly opting for other subjects in the curriculum. What the research can offer lies in the implications it has for the understanding of other contexts.

Qualitative research has also been criticised as being subjective, imprecise and biased. Nevertheless, there are checks such as triangulation (Denzin, 1978) which help to ensure that the way the research has been carried out is rigorous in itself. Sampling across different groups, such as teachers and pupils in this case, and ensuring a gender balance, as well as the use of field notes can also help to maximise the quality of the data. Reflexive research can also ensure greater accuracy by the inclusion of oneself in the research and questioning the effects of one's presence, justifying the methods used and making links between the research, theory and other literature.

## **Ethics**

The question of ethics should be central to any research. It is one of the principal features of any research that the ethics involved should be carefully analysed to consider if the research is respectful and honest. This study involved young people between the age of 16 and 18. Although they were able to understand more about why research is carried out and what is going on, I was aware that when I approached them with a view to interview, I was an adult and an authority figure in the school.

As regards the legal position, the Children (Scotland) Act, 1995 section 2 (1) gives parents the right to 'control, direct or guide, in a manner appropriate to the stage of development of the child, the child's upbringing' up to the age of 16. Children aged 12 or over are presumed to have the maturity to form views and parents must take these views into account. Full legal capacity is acquired at the age of 16 in Scotland under the Age of Legal Capacity (Scotland) Act, 1991. Since the pupils involved in this research are 16 or over, parental consent is not required on a legal basis. It is however, imperative to have the consent of any participant in ethical research and I approached the research by asking for pupils and teachers to take part on a voluntary basis.

The approach to looking for answers to the research questions was through semi-structured interviews. In this way, I hoped to explore the issues in a way in which pupils and teachers are active participants who could debate and give their own accounts and experiences.

In the pilot study, I asked the pupils their views as their current or ex-science teacher. The pupils may have felt compelled to take part, although I stressed that participation was voluntary and indeed some declined to be interviewed. Also, the pupils may have felt that I was looking for particular answers, showing science in a favourable light, although this was not borne out in practice. In fact, some pupils seemed to enjoy the chance to criticise science education and being asked to give their views was a change from normal practice and an empowering one.

It is possible that the pupils reflected on their comments after the interview and worried that they have made a poor choice of subjects to study at a

higher level, but they had already spent time in coming to a decision about course choice and the interview tried to bring out that debate.

In the research I carried out in Scotland, I was not in the position of being a science teacher to the pupils who were interviewed and worked only in a few of the first year classes. I also carried out interviews with four young people, aged 16-18 whom I knew through out-of-school activities. It was useful to have a range of participants who knew me in different capacities and this can be useful for the purposes of triangulation of data (Denzin, 1978).

In the process of finding pupil participants, I discussed with them the purpose of the interviews and the part they would play in finding out more about pupils' views on science in school. I then clarified that it was a voluntary exercise with the aim of improving science education and that they could stop the interview at any time if they wished or pass on a question that they did not want to answer. Finally, I also stressed that the tapes were kept in a safe place and would be erased when the study was complete, that no names were ever used, and that I would not discuss their personal views with anyone else.

## **Conclusion**

This chapter has considered how the research questions, which are embedded in experience and in relevant literature, were investigated. The issue of gender and science education is one which I have been interested in pursuing further for many years as a practitioner, in order to have a greater understanding of the subject matter involved in this complex field. I felt that this research should help to illuminate the questions of why girls are so poorly represented in physics and how a feminist praxis might help to redress the inherent injustice involved. The following chapter takes this process forward with an analysis of the data, setting out the results of the investigation into gender and science.

## **CHAPTER 4: ANALYSIS OF DATA**

### **Introduction**

This chapter begins with a report on the analysis of data from interviews carried out as part of the investigation of pupils and teachers' attitudes towards science which explored this interesting and complex issue from the perspectives of practitioners and pupils. The outcomes from this data were then used to begin discussions with focus groups of teachers, case studies teachers and curriculum development teachers in trying to shed light on the third research question, that of examining how a feminist perspective might be related to a new science curriculum. The chapter is set out in five main sections.

Firstly, it seemed that a diagram might be a useful way to illustrate the findings from the research. The diagram summarises the views of the contributors and shows the relationship between these and the research issues. An explanation is then given as to why the phrases were selected and deemed to be important to clarify the correlation between outcomes and context of the research. Following from this, the three research questions are explored in turn using outcomes from different groups of participants.

The second section addresses the first research question, which asks what the mechanisms are which encourage boys and inhibit girls from choosing physics. It offers a range of viewpoints from the pupils and analyses the outcomes. These viewpoints help to shed light on how the low participation of girls in physics has arisen and why it continues to be a concern for practitioners. The outcomes also indicate what the humanities subjects can offer and why some pupils find this area of study attractive. This then leads into a discussion on how practitioners felt that science education could be improved from the perspectives of the pupils.

The third section, in addressing the second research question of how teachers perceive science as a subject in the curriculum, gives outcomes from the teachers. Again, these emphasise the way science education is viewed by teachers, the different approaches offered by humanities subjects and ways in which the teachers think science education could be improved. This is followed by a summary of significant similarities and differences

between teachers and pupils' responses, 'some alternative views', a discussion of how some participants offered different views, completes the section.

The fourth part of the chapter explores the third research question by asking how a feminist perspective could contribute to a new science curriculum. It analyses the interview outcomes from the focus groups of teachers, the case studies teachers and the curriculum development teachers whose ideas for an alternative curriculum were invaluable in helping to create a new science curriculum.

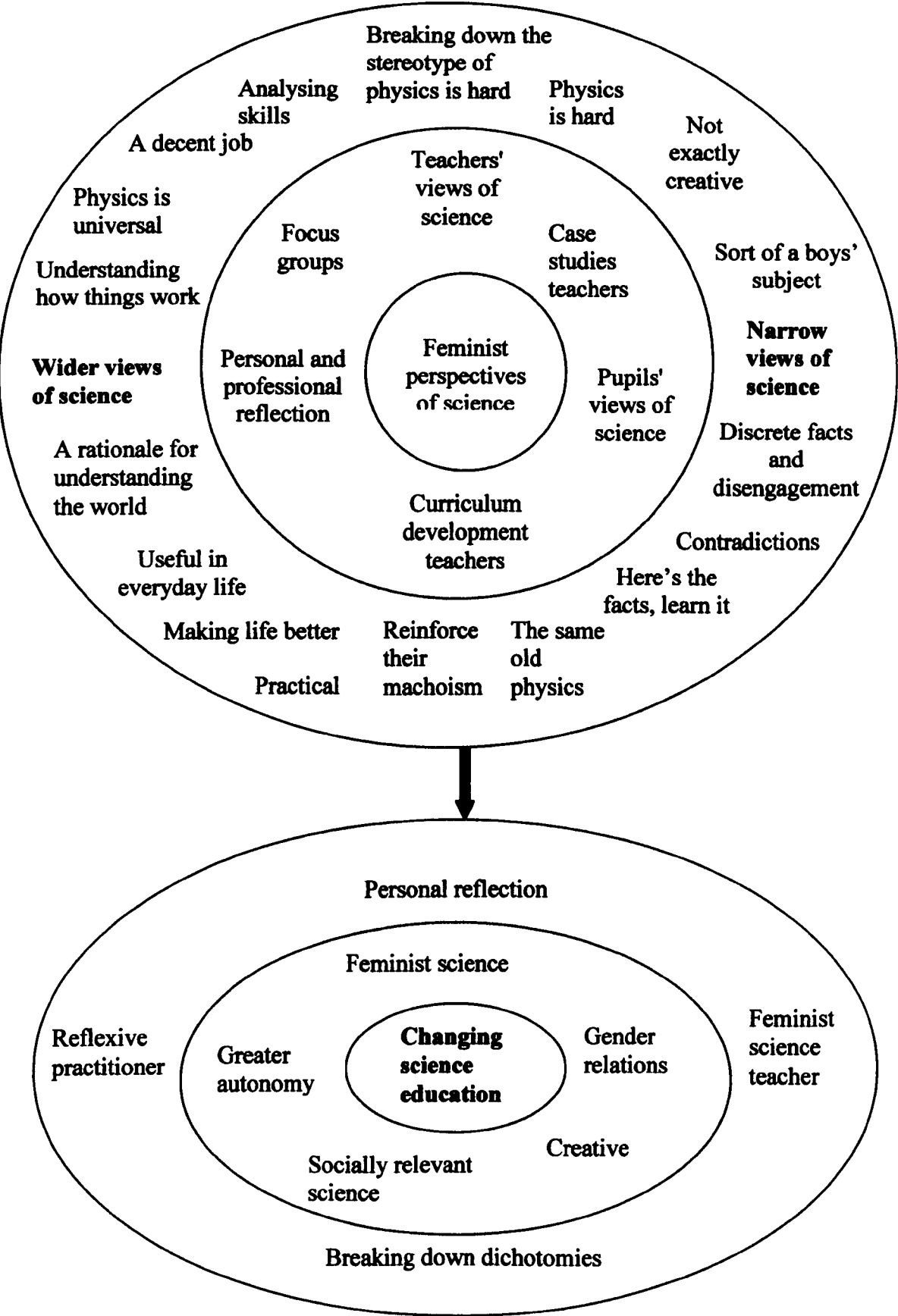
The final section discusses the implementation of the new science curriculum which was developed from the outcomes from all the interviews and analyses the extent to which it succeeded in improving science education to make it more gender inclusive.

### **A Summary of Findings**

As a means of representing the views of the participants in a summarising form, the following diagram reflects the codes which evolved out of the data from interviews with teachers and pupils. The phrases used were voiced by participants and were selected because they characterized the key issues which arose during discussion. They are important because they highlight the main benefits, as well as concerns, about science in general and physics in particular expressed by the contributors to the research.

The diagram illustrates the inter-relationship between the viewpoints of the different participants involved and the aim of the research, which is broadly to make the learning experience in science education a more inclusive one. The importance of the diagram lies in showing the way that all perspectives are valuable in contributing to changing science education.

**Diagram 4.1:** The Relationship between the Participants and the Research Issues



Feminist perspectives of science are at the centre of the diagram since the research questions are set in a framework of feminist theories, that of questioning the science that is taught, deconstructing the nature of science education and trying to improve science in the classroom by presenting an alternative science curriculum. Feminist perspectives are central to the whole study and permeate the whole approach adopted, from the research questions to the methods used and the way that interviews are carried out. For this reason, they occupy the main position around which all other aspects of the study depend.

The next layer, moving outward, is the input from interviews with key individuals and groups. The idea of placing this group collectively around the feminist centre was that the questions asked of the groups were informed by feminist theories which challenge the notion of an unambiguous knowledge based on solid foundations. The importance of my role, as a reflective practitioner, is also included in the contributors to the research.

Finally, the outside circle encompasses the spectrum of responses given. These categories are descriptive and show deconstruction of science. Although the terms “Wider” and “Narrow” views of science appear to offer contrasting positions, these mark a range of positions which participants offered with regards to their views on science education. Both categories are important in illustrating the feelings and thoughts of interviewees towards science and help in showing the images by which science has come to be viewed. However, the diagram also shows that within these terms lies a range of different viewpoints which demonstrate the richness of data collected.

All of the top concentric circles symbolise the body of work carried out in the research which feeds into the ways in which change can be effected in science education. The intention of the diagram is to demonstrate how the contribution from each circle interacts with each other and how collectively these point to changes which are possible in science education. This changing science education is in turn informed by the factors of gender relations, feminist science and personal reflection which all play a role in the creation of an alternative way of learning science.



However, the circles are not discrete entities but overlap in terms of views on science education and the purpose it should serve. There are links between the perspectives of all of the participants in their involvement in science education. In this way, I, as the researcher, am also located in all of these groups. Firstly as a feminist practitioner, then in my position as a science teacher and with my own views of science education which range from the wider views that science can benefit all to that of it being male dominated and orientated but which I am endeavouring to improve.

### **The Analysis of Data**

When transcribing the data, I began the process of data reduction by noting broad themes which emerged from the interviews. These were attributes which showed a clear acknowledgement of the way science has improved our lives and how it remains a powerful key to technology and industry in our society as well as the negative impact it has had on people's lives. The contribution which the humanities subjects have made, together with ideas of how to improve science help to point to ways in which a new science curriculum could be developed.

Data from each group is as follows: interviews with pupils, interviews with teachers, interviews with focus group teachers, interviews with case studies teachers and interviews with curriculum development teachers. This allows for cross-checking by category. In the case of the pupils and teachers' interviews, the interview questions were the same for each group and the point of the interviews was to explore their perceptions of science and humanities subjects and to see how science could be improved, which requires input from both teachers and learners, the 'givers and receivers' of education. In the discussions each research question is taken in turn and explored using the views of the respondents to illustrate their perceptions of science.

## **The First Research Question**

### **Data from Pupil Interviews**

Consideration of the first research question pointed to the need to analyse data from pupil interviews. The question asks:

*What are the mechanisms which both inhibit girls from choosing physics and encourage boys to pursue this subject at post-compulsory level?*

Interviews with the twenty pupils showed that they had informative ideas on science education. The interview questions (Appendix I) asked for pupils' perspectives of the subjects they studied. The themes which emerged were categorised according to the responses given. An example of a transcript from an interview with three pupils is attached as Appendix II.

The different types of responses showed a range of perspectives on science education demonstrating various viewpoints including those who showed an appreciation of the benefits which science has brought to our lives and others who offered a more negative view of science. These were initially divided into four broad categories: the wider views of science; narrower views of science; the approach in humanities subjects and how we could make science a more inclusive experience.

The first two of these categories correspond to shedding light on the first research question, which asks what the mechanisms are which inhibit girls and encourage boys to take up physics. The second two categories are concerned with finding answers to the third research question (creating a new science curriculum) by looking at the positive contribution from the humanities subjects and in asking pupils directly how they think science education could be improved.

The following section sets out these four different categories of responses, with an outline of each main theme. These themes are then divided into sub-categories, headed by a representative statement from the pupils followed by a discussion of this aspect and illustration using an example of the comments made by the pupils as evidence. Any extra words which I have

added for the purposes of grammar, continuity or understanding are shown in brackets.

### **Wider Views of Science**

The diagram on page 92 illustrates how data were categorised. The phrases used by pupils which showed a broader view of science, I have termed 'wider views of science'. These reflect attitudes of the learners where science and science education is seen as being productive and bringing improvements to people's lives.

Certain key words or phrases surfaced which indicated a positive attitude towards science: "useful in everyday life"; "understanding how things work"; "analysing skills" and "a decent job". These suggested the wider aspects of learning science where a more global view of science is expressed and refers to the benefits brought about through science.

#### ***Useful in Everyday Life***

The idea of science being useful to us was a theme stressed by eight science pupils - five female and three male science pupils. The participants felt that they enjoyed science as it offered a logical means towards understanding the world around them and improving lives.

*"If you can understand why things happen, you are more able to change things and make things better"*  
(Female Science Pupil 9).

This pupil felt that she had a greater understanding of the world around her and that the patterns she saw in science made that understanding easier. It is one of the premises of science that the world around us can be explained in terms of laws.

#### ***Understanding How Things Work***

The benefits of medicine and technology were mentioned by two male humanities pupils, one female and one male science pupil. They felt that the

advances made by science and resulting technology which were used to our advantage made a positive contribution to our lives:

*“If we have that knowledge, we can improve, make our lives easier, advance medically. We could discover medicine, vaccines” (Male Humanities Pupil 18).*

The advantages gained by the world through the development of science and technology were noted by science and humanities pupils alike who recognised the progress made through the understanding of the mechanisms involved in phenomena such as biological processes or engineering technology.

### ***Analysing Skills***

All of the science pupils, eleven in total, expressed a liking for experimental work in science and commented on the various skills involved in a science class, especially the practical possibilities:

*“The skills it brings are being able to analyse, to investigate” (Female Science Pupil 15).*

The pupils felt the science classes had a distinctive role in being able to offer pupils hands on work using specialist apparatus for carrying out experiments. This aspect of science education was seen as offering a unique practical skill which could be of use later in life and in a variety of occupations.

### ***A Decent Job***

One of the main reasons for opting for science subjects in school was given by one female and one male science pupils as being to do with jobs. They felt that they would have more options in the future, in terms of university courses or career prospects if they chose science.

However, three male humanities pupils also indicated that they thought that if they had more information about the types of jobs available to them then that might have affected their course choices. More work experience might let pupils see potential employment opportunities.

Pupils saw more possibilities for jobs within the science sector than in the humanities field:

*“I am going to university and these subjects will give me a wide range (of courses) to choose from” (Female Science Pupil 4)*

The status of science in our society and the common knowledge that there was a shortage of scientists meant that opting to study science could lead to more prospects in industries involved in science and technology than other types of careers available to humanities pupils.

### **Narrower views of science**

The narrower views of science reflected comments where the pupils had expressed a more negative image of science. In this case, they felt that the science education which they had experienced was not attractive and they focused on the drawbacks of studying science.

The representative statements from the pupils which I have termed ‘narrow views of science’ were: “not exactly creative”; “the same old physics”; “here’s the facts, learn it”; “contradictions”; “physics is hard” and “sort of a boys’ subject”. These views were given by pupils from both the sciences and humanities showing that even those who had chosen sciences can also be critical of aspects of its operation and organisation at this level.

### ***Not exactly creative***

The image of physics shared by two female and one male humanities pupil was that there was little opportunity to be creative, to offer opinions and to contribute something of their own ideas:

*“Probably some people like one simple answer, tables, an organised way like that, not exactly creative. In science we are not at the point of creating our own compounds. We are just leaning about something that has already been done” (Male Humanities Pupil 16).*

This concurs with the idea of physics as being facts based and not encouraging pupils to give their own thoughts on why some events happen or accepting pupils' alternative explanations of how things work which lie outside of the scientific norms.

### ***The Same Old Physics***

One of the pupils stated that although there had been various projects and some interesting experiments in his science classes, that these had been short term and had returned to physics as usual when they were finished:

*“The problem is that once (the project) it’s over, it is just back to being the same old physics” (Male Humanities Pupil 12).*

This pupil and a male science pupil felt that science coursework didn't always make sense, often because they seemed to be rushing through the course with a limited amount of time available for understanding the content and carrying out experiments to test the theory through practical work. These pupils were of the opinion that curriculum overload was to blame for rushing through the syllabus and meant that there was less time to appreciate and explore the subject.

### ***Here's the Facts, Learn It***

Another theme which emerged from the interviews about science was its content where pupils were expected to learn discrete 'facts' which led to disengagement. Science is presented as providing definitive answers to the questions people have about the world around them and these learners are often expected to accept these explanations without engaging in discussion as to the merits of the theory behind them.

One female and one male science pupil and two female humanities pupils commented on this approach in science, which the female science pupil termed as “being spoon-fed” (Female science pupil 1). She felt that there was less opportunity to find things out for yourself in the science subjects:

*“In maths or science you tend to get a lot of being spoon-fed. It is less having to go out and find the answer, it is easier in a sense” (Female Science Pupil 1)*

This approach led to the feeling by one of the female humanities pupils that science classes involved passive learning. Her view of this aspect of science education was that this was a negative factor which she disliked:

*“The experience that I have of science is that “this is it, this is the experiment, this is how it happens, why it happens, that is it” (Female Humanities Pupil 13).*

This pupil felt that there were few opportunities for debate in science classes, that the lessons were rigid in structure and left little room for analysis of the topics in science.

Nevertheless, one female science pupil noted that she preferred this approach:

*“I just like the whole fact thing that it is either right or wrong. I don't like analysis. I just want one answer, that it is black or white” (Female Science Pupil 14).*

The humanities pupils tended to dislike the approach in science classes which were seen as one of instruction and discrete facts. These pupils felt that they were not able to contribute through discussion and examination of a topic, whilst a few of the science pupils specifically expressed their liking for the way science was presented.

### ***Contradictions***

In spite of the view that science classes were ones where facts were imparted to pupils, the issue of contradictions in science arose. One female, one male science pupil and one female, one male humanities pupil, noted the confusion they felt when contradictions to expected facts or theories, occurred:

*“The teacher was explaining two things and there were two different ways to look at it because scientists are not*

*really sure about it and there are two ways of thinking about it. Sometimes theories contradict each other but in a way they are both still right, just different ways to look at it” (Male Science Pupil 15).*

Similarly, contradictions were highlighted by two female science pupils who stated that they found out when studying physics at higher levels that what had been taught to them in earlier years of science was overly simplified and actually incorrect.

For two humanities pupils, the idea of science as not producing the expected discrete facts was perplexing:

*“I couldn’t see the bigger picture” (Female Humanities Pupil 13).*

It also pointed to the need for clarification:

*“Some of them contradict each other so you want to know which is right and which is wrong” (Male Humanities Pupil 16).*

Science classes offer an explanation for the way things function in the world around us. The image which pupils have is one where science has many of the answers to explain phenomena. When doubts and contradictions do arise, the concept of theories or explanations being wrong is a difficult one for pupils to accept.

### ***Physics Is Hard***

One of the most quoted words associated with science and particularly physics was of it being a difficult subject, in spite of more pupils passing the Scottish standard grade in physics than in either biology or chemistry (Scottish Qualifications Authority, 2006). Again, this is tied in with its image as being a high status subject which only attracts the brightest pupils.



*“It has the reputation for being hard. Science is seen as an important subject to have because it is harder”  
(Female Science Pupil 8).*

Physics was seen as being a lot harder, according to two male science pupils, because it involves maths and more abstract concepts. This reflects the image physics has as a high status subject.

### ***Sort of a Boys’ Subject***

Interestingly, one of the pupils specifically made note of the gendered nature of science classes. This male science pupil was studying physics in a class which consisted of one girl and seventeen boys and felt that the subject was more readily identified with boys’ experiences in the content and approach used:

*“Electricity is sort of a boys’ subject. They have more connection with it, more interest in it” (Male Science Pupil 7).*

He regarded the topics and presentation of physics as appealing more to boys than girls and accepted as the norm that physics should be orientated towards boys. This represents the view that this field is a masculine domain to which women are neither welcome nor expected to want to be involved in.

It might be enlightening to examine the humanities subjects, an area which girls are more attracted towards, to see how the different approaches adopted in this field could point to more gender inclusive ways of teaching in science.

## **The Contributions from Humanities Subjects**

The pupils who had opted for humanities subjects showed that they preferred a different type of approach to learning. The themes which emerged from speaking in interviews with the pupils touched on the independent learning skills promoted in the humanities and the emphasis on expression of ideas and discussion in class.

I have entitled these themes using the pupils' own statements which describe the attraction of humanities subjects: "doing your own research is always more interesting" and "you get to be more creative and free". Each term will now be discussed in turn to see how pupils' perspectives of the humanities could be useful in changing the approach in science classes.

### ***Doing Your Own Research Is Always More Interesting***

The notion of developing more independent study skills which was encouraged in humanities subjects was appealing to three female pupils, one science and two humanities. The result was that pupils became more aware of different ways of thinking about a subject or were able to investigate a topic which they found interesting:

*"I think these (humanities) subjects help you to have more of an open mind" (Female Humanities Pupil 13).*

This is in marked contrast to science subjects where pupils perceived that there was little room for flexibility or encouragement of a different way of thinking about the world around us.

### ***You Get To Be More Creative and Free***

A female science pupil and a male and female humanities pupil felt that in comparison with science, with its notion of discrete facts and unchanging theories, the humanities offered more room for creativity by moving away from the concept of right or wrong answers towards being open to debate. In science:

*"You write your answer and you know it is right, whereas in English, there can be multiple answers it depends on*

*how you take the passage. Or the way you think he was writing it. There can be a lot more answers". (Male Humanities Pupil 16).*

Again, this was seen as an advantage in humanities where discussion was encouraged, allowing for exploration of a topic. The contribution from humanities then was seen as giving wider options for studying an issue and in encouraging analysis. The next section considers outcomes from the last interview question which asked how we could make science more attractive as a subject in the curriculum.

### **Making Science more Inclusive**

The underlying reason for carrying out the interviews was to explore ways in which science could become more inclusive through learning from the experiences and perceptions of pupils about how they viewed science as well as humanities subjects. In asking participants how we could make the subject more attractive, the final interview question's purpose was to collect data on how a new science curriculum could be created using the ideas from the interviewees.

The themes which emerged, again using the phrases employed by the pupils, highlighted ways of developing a more inclusive curriculum: "it's about trying to make it more interesting"; "more fun experiments" and "it is the teachers who make it interesting".

#### ***It's about Trying to Make It More Interesting***

When asked how we might make science classes more attractive, the main response from four female and one male science pupils was to show its relevance to everyday life and bring in other subjects to emphasise how the science taught related to them:

*"If they highlighted how important physics is for health. They don't realise that physics could help and it would appeal more to girls" (Female Science Pupil 8).*

This pupil felt that the bio-physics topics which related physics to human biology offered a chance to show the practical applications of physics and relate its findings to everyday life.

One female humanities pupil went further in stating that more inter-disciplinary work across the curriculum could make for a more interesting learning experience:

*“If (science and humanities) could be integrated, then obviously, everyone would prefer it because it is a bit of everything” (Female Humanities Pupil 13).*

This pupil saw the possibility of taking the more attractive elements from science and humanities to create a more inclusive curriculum, an important concept with practical implications for this research and which is discussed later in the chapter.

### ***More Fun Experiments***

All eleven of the science pupils and six of the humanities pupils, four male and two female, saw the benefits of experiments in class. They felt that pupils had more understanding and were more likely to remember the experiments, especially if these were carried out by the pupils themselves, rather than a teacher demonstration:

*“In physics, you could have a lot more fun exploring things. More fun experiments and making up experiments yourself. That would make people think for themselves” (Male Humanities Pupil 20).*

Pupil-led experiments, with sufficient time to do more practical work were cited by the pupils as positive ways in which science education could be made more attractive. Experiments were seen as opening up the ideas from science and helping to illustrate the phenomena introduced in class.

### ***It is the Teachers Who Make It Interesting***

The teachers and the influence they have were mentioned by one pupil from all the representative groups. One female, one male science pupil and one

female, one male humanities pupil felt that the importance of the teacher could not be underestimated:

*“Your teachers, that affects how you enjoy the subject”  
(Female Science Pupil 14).*

This pupil discussed how a teacher who engaged pupils could make the difference between what pupils perceived as a good class and one which they did not enjoy or connect with. The onus then was seen to be on teachers as the key individuals in creating lessons which made the learning experience a more inclusive one for all pupils.

The following section now considers the responses from the teachers' interviews. The data collected helped to investigate the gendered nature of science education further, from the teachers' perspectives and helped to shed light on the second research question.

## **The Second Research Question**

### **Data from Teacher Interviews**

The role of the teachers, as has been seen, is crucial in improving the learning experience for pupils. The second research question asks:

*How do teachers perceive and relate science as a subject in the curriculum?*

Through speaking with twenty teachers in interviews and using the same interview questions as with the pupil interviews, I was able to collect data on their perceptions of science and humanities subjects. Since the same interview questions were used, the outcomes from these interviews also echoed the four broad themes of the wider and narrower perspectives of science, the contribution from humanities and the ways in which we can improve science. In this case, the broader and narrower views on science correspond to shedding light on the second of the research questions, focusing on teachers' perceptions of science as a subject in the curriculum.

The contribution from humanities and ways in which we can improve science themes are concerned with creating a new science curriculum, by looking at the positive contribution from the humanities subjects and in asking teachers directly how they think science education could be improved. The four broad themes which encompass the outcomes from the interviews will now be addressed in turn to explore practitioners' views of their subjects.

### **Wider Views of Science**

The outcomes from interviews with the teachers which pointed to concepts that encompass a wider view of science range from the universality of physics to the way science offers a rationale for understanding the world, its benefits and possibilities for the future. These themes which emerged are headed by phrases used by teachers and indicate a more positive perspective of science. Concepts such as: "physics is universal"; "a rationale for understanding the world"; "making life better" and "practical".

### ***Physics Is Universal.***

The idea of the universality of physics and it being about common sense was put forward by two male and two female science teachers:

*“Pupils should try to relate what is really the real world with something as abstract as calculations. Physics is universal. The beauty of it is it is the same thing, the same explanation, the same laws” (Male Science Teacher 3).*

The teachers felt that accounts from a scientific perspective and scientific knowledge were accepted across the world as the main philosophy for our understanding of matter and events. They suggested that a scientific point of view offered the best explanation for the way the world functioned.

### ***A Rationale for Understanding the World***

The main feeling amongst the eleven science teachers was that the science education which pupils received should give them some understanding of the world around them. They also noted that if pupils had a greater understanding of the world through science, then they would take more care of it. The science teachers saw science as providing the answers to questions about everything around them and one physics teacher sums this up:

*“Through science, you can make informed decisions. It would be nice if people had an appreciation of what science has done for them and how great all this stuff is even although they don’t understand the detail. It helps save lives. What would happen if you stripped all that away, the mobile phones and the internet and all that and medical research and what would our lives be like? So for all the science and technology, at least the world is a better place. It contributes a rationale for understanding the world around me” (Male Science Teacher 17).*

Again, this demonstrates the power and status that science has within our society in its general acceptance of being able to explain most phenomena around us. From this stance, western science is not open to critical analysis and its biases and values are beyond question.

## ***Making Life Better***

All the science teachers had something positive to say about how science has helped us to progress and improve living conditions. They could all give examples of the technology which they regularly used or medicines which saved lives and cited these as important developments in making people's lives better.

*"We have digital cameras and interactive whiteboards. If it wasn't for physics, these things would not exist. They impact on everyone's lives. They are all to do with physics and engineering. These are all the things physicists do to make the world a better place" (Male Science Teacher 7).*

Eleven science teachers, six male and five female, gave examples of the different uses to which technology has been put and the way illness had been alleviated through the development of medicines and medical treatments, all of which depend on scientific research. They recognised the contribution made by science and technology to improving conditions for people across the world:

*"It is how the world works and you are here and you want an understanding of how it works and how you can make life better for yourself and look after the planet" (Female Science Teacher 12).*

This gave them the encouragement to motivate pupils towards taking science subjects for further study and the potential this has for contributing to medical or technological research which can be of benefit to people in the world.

## ***Practical***

That science is a practical subject was emphasised by three science teachers, two male and one female. They spoke of the skills gained by pupils and one teacher noted how some pupils could excel in this area where they might not be as academically strong:



*“Experiments go a long way. In my third year class, the ones who are struggling academically, when it came to experiments generally and especially wiring a plug, they were finished in seconds. Some of the more academic ones hadn’t finished in the period, so it provides them with a balance and I find that they respond to it well. So there is something there for everyone in the class. So each can show their strength” (Male Science Teacher 14)*

Another science teacher viewed science as giving pupils broader skills which are useful in everyday life and saw the benefits of the scientific process:

*“If you are watching the news and see a graph on the television you can analyse it properly. It is being able to look at evidence for and against things”(Female Science Teacher 15).*

Within a science class there are usually opportunities for pupils to handle equipment as well as present information in various formats. In addition, as the third science teacher pointed out, group work benefits pupils in teaching the importance of working in a team for debate and discussion of views.

### **Narrower Views of Science**

In contrast to the aforementioned opinions offered to support and justify science education, the following comments show more narrow views of science. The more negative images of science do not necessarily come from humanities teachers as some science teachers were also critical of what they saw as the narrow focus within science education.

The comments made by teachers which suggested a narrower view of science were: “reinforce their machoism”; “discrete facts and disengagement” and “breaking down the stereotype of physics is hard”. These themes will be discussed in turn in the following paragraphs.

#### ***Reinforce Their Machoism***

Perhaps the theme to come out most strongly from discussions about science and cited by three male and two female science teachers and two female humanities teachers was the awareness that physics in particular has come to be a subject linked more with boys' aspirations and experiences than girls. This association with physics was seen as affirming their masculinity:

*"They think, 'this is for me'. Plus the general, 'I am a boy, I am a very male boy and this is a male subject' and that pushes them in that direction. They want to reinforce their machoism so they go to that subject that they see as being macho" (Female Science Teacher 15).*

This concurs with the writing of Harding (1991) who discusses the way in which the scientific establishment has come to be male-dominated and reflect this gender bias in its processes and in the knowledge produced. It would not be surprising then that boys would feel attracted to a system where they felt welcomed, even if their performance in the examination system indicated that they were not strong candidates in this area.

This particular science teacher, now a physics teacher, had opted for biology instead of physics and only returned to physics after leaving school and taking the subject up again later in life.

A male science teacher who currently teaches physics agrees with the view of physics classes being a predominantly male sphere of influence:

*"Physics throughout the years has had a very male orientated, male dominated point of view and as a result that has put a lot of girls off" (Male Science Teacher 14)*

This aspect of physics classes would suggest that girls were not as welcome or encouraged in this field, which then points to the role of the teachers. Comments by the participants reflecting on their experiences of being pupils showed how much the teacher can influence the pupil in course options:

*"The science teacher said that the girls weren't allowed to answer because they would not give good answers so the boys were the only people who were allowed to answer.*

*But he would only accept right answers and that is why he only asked the boys” (Female Humanities Teacher, 5).*

The image which the subject has affects attitudes towards that subject and a class which “reinforces their machoism” would not be one which girls would feel welcome in and choose to study further. In contrast, rejection of such an image could help to reinforce a feminine identity.

One of the participants illustrated how peer pressure also affected her course choices:

*“At that point in my life, I was going with the crowd, going with the girls” (Female Science Teacher 15).*

Although this teacher had been a pupil who had obtained the highest grades in her physics class, she had felt unwelcome in this male-dominated setting and opted for biology instead which many of her friends had chosen.

### ***Discrete Facts and Disengagement***

As with the outcomes from the pupil interviews, one of the most prevalent images of science is that of it being clear-cut and not open for discussion, that an answer was right or wrong. Three humanities teachers, one male and two female showed a concern about getting things wrong and perceived that science put a great emphasis on reaching a ‘right’ answer. In contrast to the focus on finding answers and apparently unequivocal truths of science, some found this restricting and intimidating:

*“I worried that I would get a or b or c wrong, that I would choose the wrong one. Whereas, give me a 3,000 word essay and I am safe. There is only a title and I can do what I believe to be right. And nobody can tell you it is wrong” (Female Humanities Teacher 5)*

This teacher preferred the opportunity for more debate and project work which the humanities appeared to offer. It was interesting to note that she had received exactly the same grades at GCSE level in science as the male science teacher (4). However, the male participant had gone on to study science subjects and felt confident in his ability to pursue them whilst the

female humanities teacher had considered that she had not been successful in this area. Instead she saw the humanities as an area with more room for debate and closer to her style of learning.

Similarly, two teachers (female science teacher 15 and the third case studies teacher) had left school at the age of sixteen with no academic qualifications, having had a negative experience of studying physics. They had not enjoyed nor had positive role models in studying physics when they were at school and had not been encouraged or motivated to study it further. It was not until later in life that they returned to this subject as adult learners and found that a different approach to teaching helped to make the subject a more interesting one for them. These women were unusual in returning to a subject they had not been attracted to at school, since most women would have followed different routes which would have taken them along other career paths.

One science teacher also discussed the lack of possibilities for alternative approaches in science classes. He felt that there was no time for extra exploration of matters of interest given the constraints of working to a demanding curriculum:

*“Maybe if we had more project work and investigations, but there is so much in the curriculum now that the chances of doing these things are limited” (Male Science Teacher 7).*

This teacher talked about a project which was included in the programme for first year pupils and how successful it had been in terms of the quality of work produced by the pupils. He regretted the restricted opportunities for a more flexible approach by teachers which meant that this project work only covered one week of science studies in the first year of secondary science and was not repeated. The value of the project in terms of the quality of learning experience, in his view, merited its wider inclusion at all levels of science education.

His comments also highlight the view, shared by two female and two male science teachers, that the curriculum was overloaded and too prescriptive.

## ***Male Dominated and Orientated***

In the interviews with the science teachers, including four physics teachers, three of whom were male, participants spoke of the need for an image change for physics to make it more relevant. One teacher felt that the content of the courses was not appropriate, given the changes in science and technology in recent years and that the stereotype of physics had a negative effect:

*“Kids, when they come into physics, say that physics is too hard and is seen as a boy’s subject” (Male Science Teacher 7).*

This teacher described working towards breaking down the stereotype of physics as being a difficult proposition, given cultural and parental expectations, but he thought that with curriculum change and motivated teachers progress could be made.

One of the female science teachers pointed out the negative side of science and technology in contemporary life and posed the question as to whether we should be encouraging more growth in this field. Science and technology are also responsible for the development of arms and military hardware, used to kill and destroy.

However, Harding (1991) argues that to be scientifically illiterate in today’s society is to be illiterate and that we should instead be developing a science from the point of view of women’s lives, one which was responsible and respectful of the environment.

## **Contributions from Humanities Subjects**

The purpose of analysis of the contribution made by the humanities subjects is to shed light on the third research question (creating a new science curriculum) by looking at the nature of the humanities and why these subjects are felt to be more attractive by some pupils. The comments from

humanities teachers about their subject shows where the approach used in this field can be more inclusive and may point to alternatives which could be employed in science classes.

### ***Language is at the Base of Every Type of Learning***

The skills which pupils gain from humanities subjects were stressed by all nine teachers from this field. They felt that it was an important area for study in the way it empowered pupils:

*"It helps them to develop their oral skills, communication, expression, confidence, performance skills" (Female Humanities Teacher 20).*

The teachers considered that the humanities challenged pupils' views, helped them to increase their organisational skills and allowed all children, from the brightest to the less able ones, to participate.

One of the teachers talked of how supporting pupils towards success was one of the most rewarding aspects of the subject:

*"Their sense of achievement is your sense of achievement as well" (Male Humanities Teacher 19).*

He spoke of engaging pupils through appropriate texts and materials and looking for issues and information which the children could connect with at some level. For this humanities teacher, finding relevant and interesting books and encouraging creativity through expression helped to increase self-esteem and open-mindedness in his pupils.

### ***Touch Into Your Own Emotions***

In terms of bringing emotions into the classroom, one humanities teacher emphasised how the humanities draws into personal feelings and the expression of emotions:

*"Science is hard, unemotional. When you are learning a language, you have to touch into your own emotions, you*

*have to become quite humble, quite modest, because you can't talk. You are talking Tarzan when you haven't got the structure and you have to be really humble and get right in there and think right, where am I going with it? I wouldn't imagine you would be exposed to that in science" (Female Humanities Teacher 20)*

Two other male humanities teachers viewed the humanities subjects as being concerned with encouraging children and adults to reflect on themselves, their thoughts and views and consider those of other people in order to debate and discuss matters of concern.

As has been commented on earlier, in classrooms, physical sciences are presented as subjects in which emotions play no part. This is refuted in, for example, Keller's (1983) biography of Barbara McClintock's work on genetics where the author describes the value which McClintock placed on feelings and connections with the research she undertook.

### ***Never right or wrong***

Unlike science which is concerned with facts, the humanities were considered by its teachers as being able to contest matters. Hence, as long as an argument for a particular stance is supported and the reasons given as to why then there is no right or wrong:

*"You can say exactly what you want as long as you say why and you back it up to be convincing" (Male Humanities Teacher 19).*

A female humanities teacher found that developing analytical skills through discussion on issues such as democracy, injustice, inequality, racism and rights helped to teach about bias and to evaluate what they felt to be truth or fiction. This is an approach which is not often used in science classes but which may offer an alternative way of learning about science and the issues involved.

### **Making Science more Inclusive**

The final interview question, which asked how we could make science more attractive, led to outcomes which suggested ways in which science could be made more inclusive. The data pointed to two main areas for change: what is taught in science and the way in which it is taught. Again, using statements by teachers, these came under the headings of “more project work and investigations” and “making science more interesting”. These concepts are explored in the following paragraphs.

### ***More Project Work and Investigations***

An approach which was found to motivate pupils and encourage an interest in an area of science was that of pupil-led projects and investigations which gave pupils the opportunity to explore a topic which they found exciting.

A female humanities teacher described what she found attractive about one aspect of the science classes she had enjoyed:

*“The only real experiment which we did was an experiment to design a washing up liquid. And because it was so open, and because it was a long thing, we worked on it over some time, that was the only thing that I remember about science that I loved doing because you decided on the scent, the colour. Perhaps it was up to interpretation, you interpreted it how you wanted, whereas other experiments were, “you put this and that and that and you have got to have that by the end of the lesson. They put me off”. (Female Humanities Teacher 5).*

Relating the topics in science to pupils’ life experiences was seen as an important aspect to improving the science curriculum by three female and four male science teachers and one male humanities teacher. They felt that pupils were more engaged when they could make connections between subjects and real life and that this led to greater understanding and involvement in class. It also allowed pupils to see the opportunities for jobs in the subjects they were learning.

One of the humanities teachers felt that cross-curricular work and a return to thematic study would benefit in helping pupils to make links between



subjects. Hence, he envisaged that a topic could be investigated from its various characteristics, be they from a scientific, mathematical, geographical or philosophical point of view. This would lead to a more integrated way of learning involving different thinking skills, rather than looking at a subject in isolation.

### ***Making Science More Interesting***

The findings from the teachers' interviews also showed that they recognised the importance of their role in making their subject more inclusive. One science teacher saw the approaches used by teachers in the classroom as being crucial to the engagement of pupils:

*"We have to use a variety of teaching styles. That is quite important. We have to cater for people who learn by doing. We also have to cater for people who learn by listening and people who are visual learners. So we have to do a range of different things in lessons and a wide variety of different lessons"* (Female Science Teacher 6).

Three male and four female science teachers agreed that a teacher who works on encouraging discussion and attempts to inspire pupils through appropriate and challenging materials was able to improve the learning experience for their pupils. By helping pupils to have an awareness of alternatives, giving choices, allowing for reasoning and learning how to be flexible and adaptable, pupils would be better prepared for the future.

## **Similarities and Contrasts between the Pupils and Teachers' Perspectives**

Since the interview questions were the same for the pupils and teachers, the data produced touched on similar outcomes: the relevance of science as a way of understanding the world; the skills it provided and the career options it offered, as well as the negative images of science as being facts based, lacking in creativity at school level and having a gender bias.

One of the most striking differences between the pupils and teachers' responses with regards to science was that the pupils felt more strongly that the science education they received needed to be improved. There were more 'narrower views of science' from the pupils, who portrayed it as being predictable and less than challenging. However, the responses were also invaluable in showing ways in which the science curriculum could become more inclusive by analysing the humanities subjects to see why some pupils found learning in this field a more satisfactory experience and in asking the participants directly how they thought that science could be made more attractive.

The humanities subjects make use of discussion and project work to give pupils greater autonomy in terms of the content and approach to learning. This method of teaching can also be employed in the sciences to help to change the image of the "fact" driven content of studying science. In addition, pupils wanted to have a greater number of and more interesting experiments.

To summarise, the themes mentioned above show the main results from the interviews with pupils and teachers. These offer different perspectives on how participants view science and indicate how the science taught can be challenged and changed. However, some of the participants offered particularly insightful responses to the interview questions and it is worthwhile to consider how these contribute to the research data.

## **Some Alternative Responses**

In any research, there are data which do not fit into any of the categories, however loosely. These seem to give different opinions from most of the other participants about the topic being studied. In the case of this research, I found that there were a few interviews with teachers and pupils where they expressed views which contradicted many of the interviewees' comments. The three cases are outlined below.

In the first case, a female science teacher addressing the last interview question which asked how we could make science more attractive to pupils, felt that in general, her impression was that more girls were taking science and that more emphasis should be given to the underachievement of boys:

*"I think that it is not so much the case of making science more attractive to girls as trying to give the boys a good educational experience as well. I think that there needs to be more of a push to look at the ways boys learn. I think you need to try to include them" (Female Science Teacher, 13).*

This contradicts firstly the statistics showing the decline in the numbers of girls studying physical sciences and also the feeling amongst two female and two male science teachers that more emphasis should be given to girls in making the subject more attractive for them. It does perhaps emphasise the importance of inclusion for all pupils in developing a new curriculum, in not favouring one group at the expense of another.

In the second case, one of the male physics teachers showed an awareness of the problem of self-elimination by girls in physics and seemed to acknowledge that a more inclusive approach was required. He mentioned that physics was often "pushed towards cars and movement" and "irrelevant to most females", which he felt needed to be challenged.

However, he later gave an example of one way he was trying to make his physics classes more attractive through the use of video games:

*"I try to teach them about physics and decision making by making them compete against each other and choose*

*between ten cars we can race. It is fairly real life physics in the game” (Male Physics Teacher, 17).*

The teacher did not seem to see the contradiction in trying to make his lesson more relevant to girls but then using video games to do so when these are more usually played by boys and which involve the competitiveness and aggression more associated with male characteristics. The lesson did appeal to the boys in the class and shows how the idea of making science more interesting can result in making it more even more male orientated, rather than relevant for all pupils.

The third case illustrates the concerns which one science teacher had about making science more inclusive:

*“I think if you are going to get everybody involved, you are going to have to dumb it down and then I think you would take something away from science if you did that” (Female Science Teacher 11).*

However, this interview was carried out before I then worked with this same colleague to create a new science curriculum. Her subsequent change in attitude after seeing this in practice will be discussed later in the chapter.

The interviews with teachers were important for this research in helping to identify ways in which a new science curriculum could be created which would offer a more gender inclusive approach to science teaching, and this is explored in the next section.

## **The Third Research Question**

### **Introduction**

This final section of the chapter focuses specifically on addressing the third research question, which asks:

*How could a feminist perspective contribute towards a new science curriculum in order to change the approach to teaching physics?*

Using ideas from feminist theory, which involves greater analysis and questioning of science together with the outcomes from the pupils and teachers' interviews to inform the debate, I then invited key people to discuss how we might improve the learning experience for pupils in science classes.

The key participants were teachers who had shown a particular interest in working on an alternative, more inclusive curriculum and comprised of a range of practitioners: two focus groups, three case studies teachers and two curriculum development teachers. The outcomes from the interviews with each of these contributors are discussed in the following sections.

### **Analysis of the Focus Group Interviews**

The objective of the focus group interviews was to discuss, through an open interview, how we could make the learning experience a more appealing one for all pupils. By beginning with the last interview question which asked how we could make science more attractive, I sought to encourage participants to consider how we could drive this forward in order to see how a new science curriculum would look. I developed prompts for the focus groups to explore alternatives in science education and to clarify issues raised.

I have experience in curriculum development through the work I carry out in differentiating mainstream materials for pupils who have moderate

learning difficulties and used the skills involved in this role to create alternative ways of learning about science.

The interviews with the focus group teachers centred on changing the science curriculum and were interesting and informative debates which demonstrated the enthusiasm teachers have for moving science education forwards. Both interviews are analysed in the following sections.

### **Analysis of Focus Group 1 Interview**

The discussion in Focus group 1 was lively and showed the enthusiasm which the teachers have for their subjects and for encouraging more pupils into their field. The transcript from the interview is attached as Appendix IV.

The teachers felt that there were ways forward for science education and that action by practitioners and policy makers was essential to halt the decline in the numbers of science pupils as pupils opted for other subjects which they found more attractive. Although saddened by the lack of women in science, the female science teacher thought that there were glimmers of hope in terms of having a rich background in scientific research such as the example of an archaeological project where:

*“All the leading scientists were Scottish women. They were doing reconstruction and technology. They were marrying up science with history and proving the ten plagues of Egypt, but it was all women from Scotland. So I still think that it is there, but we seem to be battling against cultural perceptions. So I keep pushing women and science but the pupils still perceive physics as male”.*  
(Female Science Teacher, Focus Group 1)

The useful outcomes from this scientific investigation came from adoption of a cross-curricular approach in “marrying up science with history”, a useful approach in breaking down the science / humanities dichotomy. The work of the teachers is a key part of the process of changing and questioning

the status quo. In the discussion, the focus group covered similar points to that made by participants in the interviews.

The male science teacher commented on problems such as physics being male dominated and orientated; the perception of difficulty of the subject and the lack of role models in this field. He also noted that the majority of primary teachers are women and that their experience of science tends to be from the biological sciences, rather than physics, perpetuating the emphasis on this area in primary science studies.

This was a point taken up by the female science teacher who saw the solution as lying in supporting science teaching in primary schools and carrying this through to secondary:

*“I think that when we are asked for help from the primaries, they are asking for help with physics. (Forces and energy). And what we did in one of them was took the primary teachers out and trained them and put them back in, so there was none of this concept of physics being hard. I must say that I was stunned at the levels achieved. So there was a way forward there. It tends to be close links, close liaison with primary and secondary. It is what we are doing to change the perception of physics”*  
(Female Science Teacher, Focus Group 1)

Interestingly, the idea that the primary schools were somehow not presenting science in a positive way contradicted comments made by a male science teacher (7) who felt that primary schools did a better job than secondary schools in encouraging enthusiasm. However, he considered that this might have more to do with children’s development and self-perception. As children move into adolescence, self image becomes more important and peer group pressure exerts a stronger influence. McRobbie (1991) has written that for many girls, particularly working class girls, the subjects chosen for study at school can work to reinforce their femininity, so that in rejecting the male dominated physical sciences, they reaffirm their female identity.

It is noteworthy that the male physics teacher acknowledged that physics is stereotyped as being difficult, but appeared to be almost complicit in this as:

*“I think it brings a higher calibre of pupil as well” (Male Science Teacher, Focus Group 1).*

He did not appear to want to change this situation and this attitude is important to consider as teaching only the most able pupils might appeal to some teachers, making change in science education an altogether more difficult process, if such teachers resist alternative approaches.

One way in which the focus group felt that the image of science could be changed, would be to move away from the rigid three separate sciences of chemistry, biology and physics to create new units which overlapped the traditional boundaries, such as medical physics, which specialised in areas such as health physics and bio-technology. For the male science teacher, this was a way of changing the image of physics as well as attracting more pupils who showed an interest in biology to the subject:

*“There is a large overlap, especially in the medical physics topic. It is an area which would appeal to those who have an interest in physics but also in biology and it might soften the image slightly” (Male Science Teacher, Focus Group 1)*

To summarise, the teachers in focus group 1 acknowledged the scientific tradition in Scotland but felt that this base was being eroded as pupils were attracted to other areas of study. They saw the benefits of intervention at lower academic levels and through more cross-curricular work to try to change the image of physics. The second focus group had used similar ideas to try to break down the science/humanities dichotomy as part of a day of cross-curricular activities and their perceptions of teaching across the curriculum will be discussed in the following section.



## Analysis of Focus Group 2 Interview

This interview was carried out with two teachers, one a science teacher and one a history teacher, who were working on a project to challenge perceptions of school subjects. I had previously interviewed the science teacher and in conversation he mentioned that he would be working with a humanities teacher to try to change pupils' perceptions of science and humanities departments.

I was keen to follow up this project since these particular teachers had always expressed an interest in changing the curriculum and trying different approaches to teaching. Their comments centred on a day of interdisciplinary activities in which they decided that their main aim would be to try to break down the dichotomies of science and humanities through teaching topics in a cross-curricular way.

The teachers looked at major scientific discoveries which are part of the syllabus for both subjects. By using a variety of teaching styles, such as debate, investigation and practical work, they were able to engage the pupils in an exploration of the topic. The pupils saw how the approaches used in both science and humanities could contribute to a better understanding of the subject.

The science teacher had envisaged spending an hour talking about science followed by another hour discussing the history. However, the history teacher had another approach:

*"She said, 'no', they must learn that it happened at the same moment. So I started the lesson talking about the history and they do the same experiment to come to the same conclusions (as the early scientists). The (history and science) books had the same pages of information as well, interesting indeed. She (the history teacher) is breaking down the dichotomy of arts and sciences" (Male Science Teacher 4).*

The day was a successful one in terms of engaging the pupils and helping to challenge the dualisms in education, showing that teachers with

commitment, energy and enthusiasm can begin to move the learning experience forward in breaking down the humanities / science dichotomy.

Pupils looked at the work carried out by the early scientists as described in the history texts, debated how the scientists might have felt and lived, then went on to actually carry out the experiment themselves. This initiative gave pupils an enriching experience which brought together different subjects to show how they were inter-related and pupils had the chance to study a topic from different perspectives.

This process of breaking down dichotomies is an important part of a feminist approach, which involves a deconstruction of these terms. In this case, the erosion of the science / humanities divide was tackled in an imaginative and enjoyable way. However, this initiative needs the commitment of staff and major timetabling and curriculum changes to accommodate the change. Nevertheless, it shows that there are positive benefits for the education system through greater flexibility across the curriculum.

This demonstrates that a topic-based project of this kind has the potential to cover the study of a subject in greater depth and show how science evolved and how its development was culture dependent and influenced by the values of that society. This outcome was useful in indicating strategies which could be employed in an alternative approach to teaching science. There will be a further discussion on how this type of work could be incorporated into mainstream classes later in the chapter on developing a more inclusive science curriculum.

## **Analysis of Interviews with Case Studies Teachers**

The case studies teachers were people with direct involvement in changing science education. The first participant was a female science teacher who, as a pupil, had a different type of learning experience in a physics class. The second case studies teacher was a male science teacher who was the teacher involved in initiating this idea of an alternative approach to teaching physics. The third participant was a female engineering lecturer who had been seconded for a two year period to work on a project to encourage young people into science and engineering.

The interviews were open discussions and centred on exploring the experiences of the teachers in the teaching or learning environment in which they had studied or taught and how it had affected their attitudes or those of the pupils towards science. Again, I used prompts to reflect, clarify standpoints and help with the flow of conversation. The outcomes from the interviews with each contributor are given below.

### ***The First Case Studies Teacher***

For the first case studies participant, now a science teacher herself, the experience of studying physics with a teacher who used a different approach in his classes was a crucial step in following an engineering course at university. In the school in which she studied, there were sufficient numbers of girls who had chosen to study physics to create a single-sex class. She states:

*“The girls loved it. They felt quite special. They were all friends and it was a relaxed atmosphere. As a teacher, I worry about boys taking over. However in a single sex class, we were made to feel special.” (Case studies teacher 1)*

Pupils were encouraged to use an adjoining room as a common room and the radio played music when the girls were doing practical work. Although the lessons and examination results showed little change, many of the girls went on to study physical sciences at a higher level. This shows that there

are areas where change in teaching styles can be implemented to engage pupils and create a more positive learning environment for all pupils.

### ***The Second Case Studies Teacher***

A discussion with the teacher involved in this trial, the second case studies teacher, explored how this change in approach affected results:

*“The girls responded very positively. Evidence in an end of course questionnaire indicated that the girls preferred single sex physics classes but not for all subjects. They enjoyed the atmosphere of the class and not having to compete for equipment”. (Case studies teacher 2)*

The element of competition with boys is important here as it was not an issue in a single-sex classroom. However, as has been stated earlier, results from studies into the benefits of single-sex classes (Gillibrand et al, 1999; Younger and Warrington, 2002; Robinson and Gillibrand, 2004), have to be taken with some caution since the socio-economic background of the pupils is an important factor in exam performance. However, in this case, the exam performance was unchanged and what was different was a more positive attitude by the girls towards studying physics in this changed environment.

The unfortunate part of this case is that in spite of the success of this approach, the trial was only repeated for one more year after that, as there were not sufficient numbers to warrant a single sex physics class and the key teacher involved moved to another post. However, this again shows that enthusiastic and forward looking teachers can bring about change in science teaching through their approach to teaching.

### ***The Third Case Studies Teacher***

The third case studies participant was an engineering lecturer who had spent two years on a project to encourage more young people into engineering. Again, I asked her about her experiences of this work and we discussed the ways in which school science could be made more attractive to pupils. She stressed that it was important to show how the jobs that people do in that field were often creative and exciting:

*“Secondary science teaching needs to be got at from a different angle. Getting children to work out mathematical solutions in class means that they don’t make the link between this and working in some institution later where they will need to be creative.” (Case studies teacher 3)*

She felt that the curriculum did not allow secondary school children to enjoy the fun and personal element of science, where pupils were able to find out about scientists, their lives and how they came to discover what they did, rather than it being portrayed as a disembodied subject, detached from human lives. This case studies teacher thought that science would be more interesting if its history was offered as a way of understanding it from a person’s point of view, making it more of a human endeavour rather than a clinical application of experiment.

As with the comments made by the female science teacher in the focus group 1 teachers, this participant felt that it was important to tackle the issue at an earlier stage, in the first few years of secondary school at the latest. Part of her job had been to work on getting people into science and engineering and she organised some out of school activities on design projects to get children involved in designing and testing models, which she considered was more like the kind of work they would find in a career in science or engineering. The activities and programmes had been successful and encouraged another approach towards science education, though in the long term, this requires an extra commitment by staff and longer working hours, unless greater funding is available.

The background of this case studies teacher was interesting in that she had left school at age 16 with no qualifications and disillusioned with secondary school. It was only much later that she decided to return to studies and ended up following a science programme by chance when she could not get a place on a humanities access course. Secondary school science had not been interesting or challenging for her but as a mature pupil she had re-discovered and re-engaged with physics.

The main themes from this interview, such as including the history of science, pupil-designed experiments and making science more creative

served to illustrate ways in which science education could become more inclusive.

### **Conclusions from Interviews with Case Studies Teachers**

To summarise the outcomes from the case studies teachers, issues such as creating a more welcoming and positive learning environment, encouraging pupil-led investigations and engaging pupils by bringing the personal and creative aspects of science to light were felt by participants to be key factors which should be addressed.

These are all aspects which can contribute to the development of a new science curriculum and this will be discussed further in the next section which looks at how these outcomes can be utilised in the construction of an alternative science syllabus.

### **The Development of a More Inclusive Science Curriculum**

Teachers have a particular role to play in addressing unfair practices, redressing imbalance and creating a fairer and more inclusive experience of education for pupils. Their position in the learning process is crucial to pupils' understanding, involvement and enjoyment of lessons, as has been shown from the interviews. The ways in which a teacher can facilitate the learning process and make science classes more inclusive have been seen from the outcomes to be both what is taught and how it is taught.

The themes which emerged from the data indicated that changes in the approach to science teaching and concepts of science were required in order to progress from the current situation of the low representation of women in science. One of the main points made was that of taking the masculine bias out of science using various strategies. These took the form of adopting alternative approaches to learning using some of the processes which the humanities subjects favour, like debate and discussion to explore a topic. When pupils have more input and therefore more control and feeling of autonomy over their learning, the experience can be more meaningful (Roychoudhury et al, 1995).

The learning process is also a more gender inclusive one when the topic begins from the learner's experience. Relating the topic to the lives of the pupils can help to make it more relevant and allows the pupil to feel involved in the wider issues to which the subject matter relates.

One of the most important outcomes of the interviews generally was the need to see the science taught in schools in its social context. Often it is perceived as one other subject in the curriculum, a series of facts and experiments, unconnected with real life experiences or repeating what was known already to pupils. Within its 'social context' implies all that has shaped and continues to structure it: the history of science, the absence of women in science, how science can offer a way of looking at the world and the extent to which the science we know compares with how other countries and cultures explain the world around them in different ways.

Feminist approaches to science teaching (Harding, 1991; Barr and Birke, 1997) emphasise the need to question science and the knowledge produced. Through discussion of issues in science and the implications of science and technology in practice, pupils can gain a greater understanding of the ways in which science impacts on all of our lives, both positively and negatively. This would help to move towards slackening the constraints around school science.

To summarise, the outcomes from participants, informed by feminist methodology, pointed to changes required in science education involving:

1. The use of multi-disciplinary approaches, such as debate and discussion
2. Pupil initiated project work and investigation
3. Cross-curricular work exploring topics from the curricula of different departments
4. Emphasis on redressing unfair practice by looking at gender issues in science and questioning its role in perpetuating inequalities
5. Studying science in its social context.

All of the above approaches work towards breaking down the current science / humanities dichotomy and involve taking elements from both to create a new way of teaching and learning about science. Analysis of the wider issues from women's perspectives helps to redress the current imbalance and highlight the limited voice which women currently have in the decision making processes in science.

The employment of these strategies in science classes could improve the learning experience by encouraging an interest in and maintaining enthusiasm for science based topics for all pupils. The following sections of the chapter report on how these alternative ways of teaching science education which emerged from the data and from feminist theory were employed in some science classes. Details of the outcomes from two topics, firstly energy then water, which were presented to two first year science classes are given in the next section.

## **Energy**

The subject of energy is one taught in some form by most science education systems and therefore seemed a useful one from which to develop an alternative approach to teaching. The teacher of the class was a newly qualified teacher of physics who had taught in the school as a pupil and was working as a probationary teacher. He approached his work with enthusiasm and was passionate about engaging pupils in his classes. One of his greatest concerns in carrying out his job was with regards to covering a particular part of the syllabus which concentrated on "developing informed attitudes" (5-14 National Guidelines) towards science. This part of the syllabus asked teachers to help pupils consider how science had created both advantages and disadvantages in their lives. This lent itself to using the outcomes from the research to offer the chance for discussion of science in its social context and in doing so, to question the way it has come to be gendered. During this time, I worked with most of the groups in the class to bring out the question of the social aspects of the topic. Pupils were very aware of the energy crisis and open to debating how we have arrived at this situation.



After all the groups had presented their arguments to the class, a debate began over what was necessary and which items were not really required in our lives. This led on to how we use energy and who controls the energy resources in the world. In this way, we had adapted the questions which feminists pose to science, that of questioning the knowledge which is allowed, who benefits from it and why, to a class discussion of what energy is needed, how it is controlled and why this happens.

The discussion was rich in terms of analysing the wider issues of the topic of energy, highlighting inequalities in terms of richer and poorer countries and the role of women in this process, a perspective they had not given consideration to previously in science classes. Pupils went on to carry out a project involving some aspect of energy as part of the existing science education programme in the school. The pupils enjoyed doing the investigative work and, as previously noted, felt that more time should be given to project work in science which currently stood at only one week out of a two year period.

Some of the pupils related how they were able to use some of the ideas we had covered in the class discussions on energy to inform their investigations. Hence, instead of a factual presentation of a topic such as crude oil, with an outline of its chemical structures and distribution, they were able to discuss its wider economic and social implications. The pupils could then relate to the topic at a personal, national and global level and consider the perspectives of others in relation to the issues raised. I then spoke with the curriculum development teacher in an interview to discuss how he felt that the work had been received.

## Analysis of the First Curriculum Development Teacher Interview

The physics teacher who had worked on the development of the energy lessons felt that there was a whole range of things he would like to discuss with pupils, not just science. He was clear that there should be more discussion and that teachers should encourage children to express their opinions more. He also felt it important that like biology classes, which girls seemed more attracted to, physics should also take the approach of discussing ethical issues in relation to the science content:

*“All the approaches in biology are very good about caring, the environmental issues, saving endangered species, they are all there, issues in biology and they aren't in physics and I wonder if that is why there are more females in biology and moving towards it. I am hoping that if we can do that for all subjects, because there are issues in physics, energy and such. If you can actually make them more real and interesting and more relevant, then I am hoping that by looking at context and making them understand physics in everyday life, they might think it is more interesting” (Curriculum development teacher 1).*

This teacher saw how a different approach, particularly in the way physical sciences are taught could encourage more pupils to participate. By addressing the issue of inclusion of all pupils, the topic presented in science became one which was more engaging and interesting for all.

I wanted to try an alternative approach again with another class and teacher, using the experience from the lessons on energy to develop a different topic. The universal subject of water was being studied by another first year class and I worked with the teacher to create an alternative approach to that offered by the worksheets.

## **Water**

A discussion of why water may be the biggest issue we will face this century helped to bring out issues such as the shortage of water for certain regions of the world (or over-abundance for others), global warming, pollution and the importance of water for life. Further debate about the importance of water at a personal level then at a national and global level showed how pupils felt about the water available in this country and for other people in the world, particular in poorer regions. Pupils then prepared a short presentation on water in small groups, using the medium of their choice, bringing in the importance of water to people and the way it is controlled and shared in the world. The children created their own success criteria to assess their peers' presentations.

The pupils gave their presentations and assessed the work of other groups through an open discussion of the merits and shortcomings of their peer's work. The presentations highlighted the ways in which pupils can gain a wider understanding of issues around science and the impact it has on people through research and discussion, rather than by means of a decontextualised study of physical and chemical properties.

### **Analysis of Curriculum Development Teacher 2 Interview**

The colleague with whom I worked on the water presentation felt that generally the children had been more responsive and had shown more enthusiasm for the subject than when she had previously followed the worksheets and suggested experiments. This science teacher considered that the lessons we had developed helped to create a more inclusive science due to the approach taken:

*“They are doing something they feel good about and being successful, not just on a science level but on other levels as well, like presentation, ICT skills, cross-curricular work as well, where they could start a project in one subject and carry it through. So there is continuity”  
(Curriculum development teacher 2).*

Changing what is taught and how it is taught could help to open up science education to different possibilities. The lesson was valuable in showing that there are alternatives to ‘science education as usual’.

### **Evaluation of the Alternative Science Curriculum**

As a reflexive practitioner, an important part of the research process is that of reflection on the way education is relayed to pupils in practice. In the case of the outcomes from the research, I felt that the alternative approach adopted in the classes about water and energy led to more dynamic and exciting experiences of learning for both pupils and teachers.

I had previously attended the same science classes in the role of a learning support teacher, assisting children with learning difficulties in the lessons. Pupils in both classes had shown indifference to the subject and carried out the experiments in a detached manner, following a list of instructions without engaging in the subject or challenging the scientific facts which were taught. The questions of ‘whose science, whose knowledge and for whose benefit?’ are difficult to pose directly, but can be addressed through an exploration of the wider issues of a topic. Debates helped to bring out a feminist standpoint (Harding, 2004) in looking at the perspectives of marginalised people, and the way water and energy are resources which women are often responsible for obtaining in poorer countries.

By asking questions about the world around us, we were able to open up discussion further from one of mere product and process, which tends to be how subjects are traditionally treated in science classes, towards widening understandings of how these issues affect all people in the world. The debate was designed to begin with the experiences of the learner and to relate these to a wider field. In doing so, the pupils saw how their experiences were part of a greater concern, connected with it and through it with the experiences and preoccupations of others.

It has been a criticism of science from interviews with pupils and teachers who have opted for humanities subjects that science often leaves out the “bigger picture”. This type of involvement can help to open up the subject

to show the inter-connectedness of the topic with social, political and gender issues.

## **Conclusion**

This chapter has brought together the main points made by pupils, teachers, focus groups, case studies teachers and curriculum development teachers in the study. The respondents' comments suggested changes which need to be made to science education if the scarcity of women in the field of science is to be challenged and progress made. Science education needs to be changed, in terms of content and approach, to restructure and eliminate inherent gender-biased attitudes. A summary of categories of responses from all the groups is given in Appendix VIII.

The third research question asked how a feminist perspective, that of working to improve women's lives, criticising dominant systems of knowledge, being praxis-orientated and imagining different possibilities (Weiner, 1994), could contribute to a new science curriculum. I have sought to create a more gender inclusive approach to teaching science using the approaches in humanities: discussion, pupil-led projects, presentations, and investigation of a subject. This emphasises questioning the wider issues of a topic, rather than concentrating on scientific facts. The success of the classes showed the potential for engaging all pupils in science education on different levels and the following chapter explores this further with an interpretation of the outcomes.

## **CHAPTER 5: INTERPRETATION OF OUTCOMES**

### **Introduction**

The outcomes from data from the interviews with all participants pointed to ways in which science education can change to make it more inclusive for all pupils. Essentially, the initial pupil and teacher interviews shed light on the first two research questions directly by showing the perceptions which pupils and practitioners have of the science they learn and teach. Further open interviews with focus groups, case studies teachers and curriculum development teachers helped to illuminate the third research question. By using the responses and outcomes from interviews, I was able to create a new science curriculum with colleagues and this was put into practice in two first year science classes.

The object of this chapter is to crystallise the main outcomes from the data, discuss these in the light of key concepts from literature and present the conclusions and interpretations drawn. A summary showing categories of responses from all the interviews is attached in Appendix VIII and this demonstrates the range of outcomes using comments made by the various participants. The results pointed to ways of creating a more inclusive curriculum, that of making science more interesting through changes in the content and delivery of the subject.

The rest of this chapter will look at each theme in turn to analyse the outcomes from the research. Firstly, outcomes from the narrow views of science will be discussed, then those from comments relating to the contribution from the humanities. The third section will address the creation of a more inclusive curriculum, through changes in the approach to teaching physics.

## **Narrow Views of Physics: Gendered, Facts-driven and Hard**

The research I have carried out aimed to address the problems highlighted by the narrower views of the school science curriculum: that of it being seen as gendered, facts focussed, of high status and difficult. Although there was wide recognition of the benefits of science generally, in terms of the advances it has made in medicine and technology and as a way of understanding the world, there was also criticism of the science, particularly physics, which is taught in schools as being gendered, dependent on learning facts and repetitive. A discussion of these impressions of science education follows, in order to point the way towards how it might be changed.

### ***Identifying with the Subject: the gendered nature of science***

Industry and technology depend on research in physics and given that more men have followed a physical sciences course, there will be more men present in this field and their writing will reflect masculine values (Haraway, 1989).

The scientific establishment is a male dominated culture which has excluded women from participating in this world through its structure and practice (Harding, 1991). Data from the interviews confirmed the view that physics is seen as being more of a boys' subject to which men might feel more welcomed, even if their intellectual ability was not greater than that of women.

Both pupils and teachers noted the gendered nature of physics in its male-orientated approach to teaching. The adoption of more gender neutral examples in experiments and texts would be one strategy which teachers could adopt. Examples from texts tend to involve experiences with which boys would be more familiar and girls would feel that they didn't quite belong in the class. Teachers therefore need to ensure that they include topics and examples which are relevant to all pupils, rather than favouring one particular group.

However, in a classroom situation, a teacher can see from the pupils' reactions whether they are engaged in the subject or not and in the case of

this research, pupils openly voiced their opinions as to whether they felt that they could connect with the science education they received. Greater discussion with pupils and reflection on the practice of science could create a more inclusive curriculum.

In addition, there is a need for critical studies in the field of science, such as is practiced in literature or art. Harding makes the case for a “science criticism” (Harding, 2006, p.62), like literary criticism, and science education should also be held up to scrutiny to help identify areas of gender bias in science education.

The experience of some teachers was that a lack of role models and peer pressure had affected course choices, highlighting the way in which identity and identifying with the subject is a crucial factor in deciding on a field of study. This was an area researched by McRobbie (1991) who found that working class girls reproduced themselves through their actions and this included choosing certain subjects, in order to reaffirm their femininity. By self-eliminating from a male dominated subject, the girls assured that their image was feminine and dissociated from masculine tendencies.

Again, this indicates the importance of transforming the image of physics as a male dominated and orientated subject. However, it is a difficult situation to change when many of the role models in physics are male. Nor is it an easy process to scrutinise one’s own practices to look for gender bias. Nevertheless, the experiences of these contributors present a strong case for a break with current practice in the physics education curriculum.

The data showed that in spite of achieving high grades, some women teachers rejected physics at school. They later returned to it through access programmes, illustrating the need for change to the physics curriculum at a school level if the situation of the low participation of women in this field is to be addressed. Programmes allowing direct entrance to university courses can offer an interesting and relevant approach to physics and later entrance avoids the difficulties of youth peer pressure and socially constructed barriers of image.

### ***Objectivity and Facts***



The emphasis on facts in learning about science was an important factor included in the narrower views of science, and data showed that from a pupil's perspective physics consists of a body of knowledge which has to be understood by learners in order to be seen as succeeding in this area.

The relevance of this body of knowledge to the pupils' lives was not always apparent to the pupils (Gilbert, 2001). Also, the over-emphasis on content in science which does not challenge the children (Osborne and Collins, 2001) was articulated. Teachers felt under pressure to cover the work in the time allocated and clearly an over-loaded syllabus presents difficulties for pupils and teachers, an issue which needs to be addressed through changes to the curriculum.

In addition, the presentation of 'facts' can bring tensions since, as science pupils can discover within their school career, the 'facts' are shown to be uncertain (Stark and Gray, 1999; Roger and Duffield, 2000). Hence, simple explanations given to science pupils at elementary stages are replaced by more complex concepts as studies continue to higher levels of theory. Pupils are taught that some hypotheses are only valid under certain conditions and the 'facts' given to learn about laws and models of the universe might only occur within specific parameters. This created anxiety on the part of the learners and a feeling that teachers contradicted themselves.

In trying to explain these concepts, it would seem like a good opportunity to discuss the way scientific theories evolve, are not absolute and fact producing, but instead depend on current perspectives which offer explanations for debate. The idea of science teaching as being facts-driven suggests that there is a 'truth' to be discovered and that the scientific process is an objective one. However, the idea of objectivity is problematic since, as subjective human beings, we all have our own perspectives and experiences and these affect our viewpoints.

The concept of objectivity in science is refuted by Kuhn (1970) who notes that outcomes and interpretations from research which then lead to theory, arise within the framework and particular culture in which the scientists work. Hence, theories are developed in science until discredited and replaced by other models in a manner of constant evolution. In such a way,

scientists' perceptions are paradigm laden, making the idea of objectivity a flawed notion.

Since science is therefore culturally dependent, the historical background and context of all knowledge claims must be analysed at the same time to have meaning, as Harding (2006) suggests:

*“Mainstream objectivism’s value neutrality is an impossible goal to realise, since we can never completely transcend the conceptual constraints of our particular historical moment. And it is an inappropriate goal because it blocks trying to understand which values and interests in practice do advance the growth of knowledge”*  
(Harding, 2006, p.85)

Her call for “strong objectivity” is not only being conscious of gender bias but of transforming this to change the current situation resonates with the research I have carried out.

In developing the science curriculum, teachers could encourage greater discussion of the way theories were developed and open this up to debate to give pupils an understanding of the processes involved in the creation of knowledge. This is an empowering process as it encourages the pupils to reflect on what counts as legitimate knowledge, why it is accepted as such and also to help them form their own views and have a greater understanding of the context in which ‘scientific facts’ are produced.

### ***Dominance and Degree of Difficulty***

Another issue raised by the first focus group was that of the dominance of the western countries which has come about through research in science and the resulting technology. They feared that as the economically emerging countries of the east developed their industry and technology, future generations in the developed world would not be able to compete, resulting in other countries becoming dominant and western hegemony diminishing.

There are inherent tensions apparent here as this demonstrates how science is perceived as being the key to economic prosperity. Harding (1998) writes of how scientific development led the way for western dominance through

industry and technology which in turn equates to power. Without that power or with less power, western countries could not be as globally influential as they are currently. The data illustrated ways in which people can find dominance acceptable and relinquishing that power difficult, when they themselves are in the dominant group.

Physics is often projected as a high status, difficult subject (Murphy and Whitelegg, 2006) and there is a tendency for only the more academic and predominantly male pupils opting for physics at a higher level. Some teachers appeared to have an attitude of acceptance of this practice, though it would not be unusual for a teacher to want to teach a class of very able pupils since this in turn would produce better examination results, which then reflect well on the teacher.

More able pupils who have selected this subject would learn more easily and be less demanding for the teacher in terms of requiring further or alternative explanations for observations. They would also be less likely to present disruptive behaviour which often results from less able and less confident pupils. It would then be in the interests of the teacher to wish to maintain the exclusive status of the subject, thus reproducing the way the education system functions.

### **The Contribution from the Humanities: Engagement and Expression**

Science educators can look to the humanities to see why pupils would find this to be an interesting area to engage in, in order to inform their own practice. The humanities subjects were perceived by some pupils as being dynamic; open to debate and encouraging free expression. Pupils who had decided to follow humanities subjects mentioned that they enjoyed being given the opportunity to interpret and analyse topics in class. This contrasts with science lessons, where pupils' opinions are given less precedence, resulting in more limited opportunities for discussion and debate. The lessons for science then lie in valuing subjectivity and experience in the curriculum as is the case in humanities classes (Rosser, 1990; Letts, 2001).

The research I have carried out has similar outcomes in this respect to research by Tobias (1990) who enrolled humanities students to critique science courses in order to see science from humanities students' perspectives. The participants cited the lack of discussion, the omission of an overview or seeing the "bigger picture" through making connections between different areas and tasks, interweaving ideas and theories and being creative with the science given as reasons why they found humanities which encompassed many of these notions as being more attractive and enjoyable to study.

Tobias (1990) points out that the science which is learned in school does not have a great impact on the science learned in later studies and as such, it should be possible to create an alternative science in school which would encourage more pupils to pursue this field. In turn, the scientific community itself has to be open to accepting non-traditional students and ways of learning. Tobias (1990) felt that "even students not yet *demonstrably* inclined to science will respond positively to special attention, curriculum enrichment, and personal opportunity" (Tobias, 1990, p. 92). The contribution from the humanities in terms of presenting topics which are open to critique and debate is vital for incorporation into a new approach to science teaching.

Science is also concerned with ways of talking and thinking about the world and Foucault (in Rabinow, 1984) stresses the importance of analysis of such discourse. When the prescriptive approach employed in science is scrutinised, the values assumed from the scientific establishment are exposed. In this way, the biases in the practice of learning about the subject, which presents itself as objective and value-free, are brought to light. More analysis and discussion of the processes going on in science classes would give pupils a greater awareness of the assumptions made by science and the knowledge it permits.

Within the field of science, Barton (1997) sought to engage her pupils in questioning the terms and processes involved in science, a deconstruction of accepted truths and language in order to construct a new science education for all. However, Barton was working at tertiary education level and this analytical approach is perhaps easier to accomplish with university students

than with secondary school pupils. The research I have carried out emphasises the need for intervention at a much earlier stage, in order to engage pupils before they opt for particular disciplines.

The data which emerged from this study indicated that there should be more debate in science, not only around a particular topic, but also why that topic is deemed to be of interest. This is one of the main objectives by feminist critics of science as it stands (Rosser, 1990; Harding, 1991) and would move the issue forwards, contesting the drive for facts and knowledge in science.

Humanities teachers and pupils mentioned the importance of learning analytical skills which teach about bias and involve questioning not only the nature of the issue but also the processes and influences at work in the context in which it exists. In humanities subjects, pupils are actively encouraged to debate and deconstruct words, terms and ideas, with no right or wrong answers, rather through discussion and evidence to justify a particular opinion (Tobias, 1990). It is this approach within the humanities, and generally lacking in the physical sciences, which pupils have indicated is something they find attractive about humanities subjects. Pupils are generally not encouraged to question the 'facts' given in physics, but a deconstruction of the term physics might expose gender biases (Gilbert, 2001).

It would seem that the approach in the humanities does have much to recommend to science, and physics education in particular, in offering the opportunity to open up subjects to analysis. But how can these alternative ways of teaching inform science education? The content and approach to teaching science can be changed through the adoption of different strategies and the following section outlines ways in which progress can be made.

### **Creating a More Inclusive Science Education: Changing the Learners' Experience**

What would it mean in practice to integrate feminist epistemological analysis of the way scientific knowledge has been produced into mainstream

science classes? This is a challenging task as has been pointed out earlier, since the science education which exists in classrooms today has altered little in many decades. However, a change in approach towards science education can improve the experience of learning by including all pupils if there is enough positive intervention at an early stage and the challenge for practitioners is to work towards this goal. Teachers who currently practice have themselves been pupils in the system, following similar styles of teaching and learning which they then reproduce in their classrooms. The syllabus (5-14 National Guidelines) sets out a series of topics which would have been included in guidelines from fifty years ago, which upholds the writing of Bourdieu and Passeron (1977) who comment on the way social structures are reproduced in society. The data suggested a tradition of physics education teaching and content which has changed little.

However, it is possible to change the style and content of physics classes and create a new science curriculum informed by feminist theory. The way forward is through the efforts of the teachers and the approach to learning. Pupils and teachers felt that teachers held the key to trying to make lessons more interesting and there was a recognition that practitioners needed to adopt a different approach if they were to engage and involve pupils more in science education.

Nevertheless, caution is advised: a physics teacher who brought video games to the physics lesson showed that teachers can sometimes feel that what they are doing is making their lessons more exciting for all their pupils when they were in fact making them more exciting for the boys in the class (and perhaps the teacher). This could be avoided by greater reflection on practice from the teacher, in asking themselves 'who benefits?' from changes in approaches and asking the pupils their opinions on the changes. Science can be shown to offer a particular perspective as part of the overall context of society and the teacher has an important role in this process. Teachers need to engage both female and male pupils through involving their lives in the learning experience, a primary concern of feminist standpoint theory (Roychoudhury et al 1995).

As has been seen earlier in the literature section, there are examples of topics being approached differently, informed by feminist theory, in order to

engage girls more such as using medical physics examples in teaching mechanics (Hoffmann, 2002). These were popular with all pupils and did not rely on gendered cultural experiences to be understood so therefore did not disadvantage one set of pupils over another who may not have had that previous knowledge.

Although the incorporation of single-sex physics classes has shown some success (Gillibrand et al, 1999; Younger and Warrington, 2002; Robinson and Gillibrand, 2004), this is not always possible within a co-educational school given difficulties with timetabling issues and ensuring viable class sizes. Instead, an atmosphere of “feeling special” might be a feature of all classrooms, since all children would benefit from being made to feel special, and one of the outcomes from this research has been to show that greater pupil involvement through discussion, debate and questioning values of science and of themselves can lead to greater inclusion for all pupils. The aim of this research was not to benefit one group over another, but rather to improve the learning experience for all pupils in science classes.

The ideas for change from the participants in this research were to make science more interesting for pupils by changing the way it is presented and the subject matter which is taught. This could be achieved through the inclusion of more interesting work and experiments and for teachers to try to engage pupils more by means of debate and analysis; projects and investigations and cross-curricular work. Throughout all of these strategies, relating science to personal and life experiences; emphasising the social context of science and holding science up to scrutiny (Harding, 1991; Hughes, 2001) were seen to be ways forward for creating a more inclusive science curriculum. These concepts will be discussed in the following sections.

### ***Debate and Analysis: breaking down the boundaries***

One of the main outcomes from the research has been that the approach in science classes needs to be changed in order to engage pupils more in the subject. The way in which a topic is delivered can make the difference between generating interest and creating a dislike for the subject. Encouraging children to express their opinions and question their beliefs can

help them make sense of a topic. Implementation of the new curriculum also gave rise to a more socially relevant science, one in which the children could relate to the issue concerned at different levels, from the personal to the global.

The humanities use strategies such as debate and discussion to analyse subjects and these can be employed in the sciences to help to break down the dichotomies which exist between the two disciplines, opening up science education to analysis and reflection. There are common goals in the arts and sciences in terms of learning more about the world we live in and both can contribute to making us more informed and tolerant people (Tobias, 1990). This process of breaking down dichotomies or the boundaries between subjects is an important part of creating an alternative science education and one of the main tenets of feminist theory (Gilbert, 2001).

It is worth commenting on the differences between the approach used in the biological, as opposed to the physical sciences, since many topics studied in biology, such as evolution, global warming and the greenhouse effect are open to debate and discussion, given their impact on everyday life and current world issues. Teachers of biology noted that the pupils seemed to be more engaged and brought their ideas and perspectives to classroom debates on environmental issues during discussion time. It is important to make lessons relevant to the pupils and spark an interest in global problems through relating these to the pupils' experiences. It is also the case that assessment in biology allows more room for opinion through essay type questions.

However, physics classes have less of a tendency to involve the wider examination of a subject, with a concentration on specific areas, focus on theories and study of discrete and dissociated sections, assessment of the pupils' ability being measure through success in problem solving. This leads to narrowing the relevance and limiting the scope of this subject. In addition, assessment involves less writing and a tendency towards questions which ask for short answers or numerical values, which restrict the possibilities for expression.



In the case of the new science curriculum implemented in the science classes, we used approaches adopted by the humanities towards investigating a topic through debate to question beliefs and values (Tobias, 1990) and also through discussion on the wider, global implications for the issue. This can help to soften the image of science as an objective, facts-driven subject and help to create science classes which are more relevant to the pupils.

The implementation of two topics which were taught in a different manner with an alternative focus showed that it is possible to create a more gender inclusive science. I noted that the pupils showed a level of enthusiasm for the subject when they had more autonomy over what they studied within the parameters of the topic. They were able to find an aspect of the subject which they could engage with, then share this with peers, offering it up for debate and analysis. A shared decision on learning outcomes and success criteria gave the pupils greater control over what they thought was important in an investigation and how this might be assessed.

Like Roychoudhury et al (1995), Barr and Burke (1997) and Barton (1997) this research used a feminist pedagogic approach to teaching, in focusing on improving women's lives through analysis of gender relations, being open to change and encouraging pupils to be creative. However, unlike the aforementioned authors, the research I have carried out was with younger secondary school children, rather than adults. As such, it has an original contribution to make to the body of research, as I am a feminist practitioner working in science education. This allows me to work directly with the children who will make choices in the future about the type of career they would like to follow. My role affords me the unique opportunity to bring about change in science education and to create an atmosphere of curiosity and enjoyment about science through the adoption of inclusive practices in the classroom. These aspects of the research mark it as distinctive in its contribution to investigation in this field.

### ***More Project work and Investigations: Water for Life!***

For some pupils, the image they have of physics is one of being given information and having to learn and reproduce this, rather than making their

own discoveries and drawing their own conclusions. The merits of project work are that it can offer a more flexible approach to learning by placing some responsibility on the pupil for their learning (Rosser, 1990). In this way, pupils have more control over their own learning rather than being passive learners as is currently often the case. By investigating a subject which may encompass different areas of learning through exploration of an area of interest, pupils make connections with different areas of the curriculum and with life experiences. This can help to move away from the masculine image of physics as one of discrete facts and open up a topic to investigation through a wider context.

Comments by science teachers suggested that the topics they were obliged to cover within a tightly bound national syllabus left little room for adopting alternative approaches to teaching and learning, which they knew to be successful and popular amongst all pupils. This included pupils carrying out their own project work, though this was limited to a short time in the science education programme. Results were very impressive and pupils showed a real enthusiasm for this work, often spending much of their free time on their projects to find out more and to try out small experiments themselves to see how they worked. This raises the problem of constraints on time for project work from a heavily packed curriculum which puts pressure on teachers to cover the syllabus.

In the case of the project work which I implemented through the themes of water and energy, this allowed pupils the freedom to explore the issues and gave them some autonomy over their learning by pursuing lines of enquiry and delving into aspects of it which would not be possible within a tightly controlled syllabus. In carrying out project work, pupils were encouraged to be creative in their approach, which outcomes suggested was essential since science research requires a great deal of creativity. This is not a concept which is being relayed to pupils who indicated that they felt science to be decisively uninspiring at school level.

If physics is to improve, attention must be paid to the ways in which it is taught to pupils. The clear messages from the responses were of science being facts-driven, not open to creativity and gendered. These factors need to be addressed if we are to change the experience of learning in a science

classroom and the implementation of an alternative curriculum has shown that this is achievable.

### ***Cross Curricular Approaches: Making Connections***

When children's experience of education involves a cross-curricular approach, where a topic or theme is explored through debate, investigation and experiment, then the learning process can be a more enriching experience for the pupils and one where the dichotomies of science and humanities are broken to allow for exploration of an issue.

The second focus group outlined an initiative which gave pupils the motivation to learn about a topic from different perspectives and brought together different subjects to show how they were inter-related. Pupils had the chance to study the art, science and history from the renaissance period and see how each was affected and influenced by the other. This idea of bringing in experiences from other classes to pupils can help to make science education more inclusive. By exploring topics in a cross-curricular fashion, encouraging an overlap in approaches, subjects such as art, history, music and science might be taught through a more thematic approach to give pupils a wider understanding of people's lives and circumstances and placing science in its social context.

It is interesting to return to the work of Tobias (1990) whose research involved using non-science students to critique introductory science classes and comment on their experiences. The participants reported that they wanted to know how things in science had come about, why scientists understand the world the way they do and the connections between what they were learning and the larger world. Using a cross-curricular approach would help to provide the kind of overview that the students felt was missing from their science studies, through an exploration of the historical, creative, personal and social as well as scientific aspects of the whole subject matter.

The current implementation of the Curriculum for Excellence in Scotland arrives at an opportune time for changing physics teaching. It offers greater potential for cross-curricular activities by encouraging a more thematic approach to learning and stresses the need for "ensuring connections

between all aspects of learning” (Curriculum for Excellence, Newsletter 7, Spring 2008, p.1), suggesting that teachers help learners explore a topic by looking at its wider context. The recommendations from the research I have carried out and putting these into practice are relevant to the new policy for education in Scotland and will be examined in the next chapter.

## **Conclusion**

This chapter has focused on the outcomes from data collected from interviews with people involved in education and how they can inform practice. The outcomes show how teachers reflect on their work and the ways in which they see progress as being possible within the confines of their teaching responsibilities. It also demonstrates the optimism they hold for the future of education in this field and the perception that alternatives exist and that there must be change to the present system. The perspectives of pupils are also crucial in establishing why they participate in this field or opt for other subjects.

Although there are difficulties in changing a long established physics teaching tradition, it is one which is required in order to move the current situation forward. The challenge for teachers is to consider the implementation of different approaches and teaching strategies to change the image and perceptions of physics, with the outcome being greater inclusion for all pupils.

Constructing a broader and more relevant science education using feminist theory is a large and complex task. ‘Science as usual’ has not changed substantially over the past few decades in the same way as humanities subjects have, with more debate, analysis and greater access to data. However, part of a feminist approach to research, feminist praxis, is not only concerned with investigation but also bringing about change wherever exclusion exists. The third research question asked how a feminist perspective could contribute to a new science curriculum and, as a practitioner, I was able to look at a few topic areas of the physics syllabus and to try and approach these differently. By using the information relating to the negative aspects of science education, together with the contributions

from humanities and the suggestions for improving the learning experience, I created a new science curriculum with colleagues which was successful in engaging all the pupils in the class and demonstrated that adopting a different approach is feasible. The outcomes from this research have implications for the wider education system and the recommendations which arise from it will be discussed in the next chapter.

## **CHAPTER 6: RECOMMENDATIONS FOR SCIENCE EDUCATION**

### **Introduction**

As the research has indicated, the current approach to teaching science serves to perpetuate the exclusion of a large number of pupils, the majority of whom are female. This matters for two reasons. The first is that almost half of the population is excluded from being part of the scientific establishment and also that the contribution of women is lacking in the knowledge which science produces, rendering it intrinsically incomplete (Birke, 1986; Harding, 1991; Rose, 2004). Incorporating a feminist informed approach within this new science curriculum, one which is: political, critical, praxis-orientated and creative (Weiner, 1994), could help to redress some of the inequalities which science education incorporates through its practice and policy.

This study recommends changes in two main areas, that of the curriculum and in the approach to teaching, essentially, what we teach and how we teach it. What we teach is defined through the policy which underlies science education and how we teach it depends on science teachers and the content of the curriculum. The recommendations therefore have implications for policy makers, teachers and curriculum developers and these can be summarised as follows:

#### **At a policy level:**

- Promote greater inclusion by placing gender issues to the forefront of a new curriculum which challenges assumptions about gender and moves away from the exclusion of women from science.
- Use gender monitoring to highlight areas of inequality and imbalance.
- Streamline the curriculum to create continuity across the different stages of education.
- Reduce the number of topics in the curriculum but introduce more cross-curricular and interdisciplinary work.
- Change assessment outcomes to include more use of formative assessment.

**At a teaching level:**

- Examine a theme through questions starting from a personal perspective then consider the gender issues involved, being a responsible citizen, the ethical and moral issues, as well as the national and global implications for the topic.
- Make greater use of group and whole class discussion.
- Use more project work to explore issues in small groups.
- Promote cross-curricular studies.
- Use peer assessment in a variety of formats to ascertain whether the agreed learning outcomes have been met.
- Value the pupils' experience and allow time for reflection.

**At a curriculum content level:**

- Link science to other curriculum areas such as social subjects, religious and moral education, health, communication and information technology.
- Include gender equality, female occupations and gender issues in the topic.
- Question the science which is given and consider the context of its development.
- Reduce the content of the syllabus to give more time to study topics in depth.
- Explore subjects from a global perspective and include social concerns and ethical issues.

This chapter continues by giving more detailed recommendations relating to the three major areas above: for policy makers, teachers and curriculum developers. It includes an illustrative curriculum showing the approach to teaching a topic such as energy, water, the environment or health and then outlines the way in which current changes to policy, through A Curriculum for Excellence, might lead to some of these recommendations being put into

practice. The chapter concludes with a consideration of further research and research questions which lie beyond the scope of this research but are related to it and which could provide valuable insights and extend our knowledge of this field through investigation.

### **Inclusivity in Policy and Practice in the Science Curriculum**

The ways in which pupils experience education depend on policy, be it at a school, local authority or national level. Policy has the power to influence different aspects of the learning process and good policy is important in creating effective learning conditions.

The recommendations from the research I have carried out have implications for policy in terms of gender, inclusion, curriculum development and assessment and each of these factors will be discussed to see how policy should address these issues.

#### ***Gender in Policy Development***

Ensuring that the gender question remains a priority in developing policy in science education and keeping gender issues to the forefront of discussion on change in science education is essential. The curriculum I have developed and the approach taken has the potential to initiate fundamental change in the way science is taught. Gender issues must be at the forefront in the debate in science education, if not, current resources and approaches may continue to be utilised, without a real shift in practice. The objectives of encouraging children to look at the wider picture and to develop an understanding of the big issues in science are a crucial part of the findings from the research I have carried out and included in this is the need to engage in the issue of gender.

#### ***Inclusivity in the Science Curriculum***

There has been a focus in recent times on policies to promote inclusion (Section 15 of the Standards in Scotland's Schools etc. Act 2000) and this includes a move towards the creation of a more inclusive curriculum for all pupils. Since "inclusive education is based on a philosophy of the positive



valuation and celebration of difference” (Swain and Cook, 2005, p.59) there are implications for the way that science education in particular could use this as a basis for change.

Inclusive education is concerned with valuing all pupils (Armstrong et al, 2000) and implied in this is the need for a re-evaluation of the curriculum and the approach to teaching. However, the research I have carried out has found that in order to achieve this, the gender dimension needs to be made more explicit by policy makers for teachers and pupils.

Feminist standpoint theories (Harding, 2004; Hekman, 2004) go further in promoting inclusive practice by beginning with women’s lives and acting as a “counterhegemonic discourse” (Hekman, 2004, p.232) to the current science which incorporates masculine values. There is a need to redress the existing imbalance through greater emphasis on the experience of women and implementing this through changes to current policy and practice. The topic of water for example is one which lends itself towards discussion on how and who obtains this precious commodity in poorer countries. This can then lead pupils to reflect on the vital role of women in its acquisition.

### ***Restructuring the Science Curriculum***

The issues which I found to be of importance through carrying out this research pointed to the need to restructure the science programme, particularly in the early years of secondary where impressions about science are formed by pupils. At the moment, there is little cross-over between primary and secondary science and this is an area which could be improved upon. This lack of knowledge of the nature of primary level education leads to repetition of topics which pupils find unchallenging and boring. It also shows that there would be time for alternative approaches if the curriculum were realigned from pre-school to the end of secondary level. Yet the crucial stage of the first few years of secondary is a time when pupils decide on subject choices and future careers and it is imperative that schools use this short space of time to show that science is dynamic, needs creative minds and is fundamentally a human process.

Scientists working in the field of science at the research and development level need to think creatively in order to push the boundaries of what has

been possible, to move forward. It is this sense of progress and change which needs to be passed on to pupils in the early years of secondary school to engage their interest in thinking beyond what has already been achieved and also to examine the content of the science curriculum and the values it holds. While this is difficult in a classroom setting, there are nevertheless opportunities to encourage debate and question the science taught and the way science has become gendered.

The type of assessment used in schools is the driving force for the way the curriculum is implemented. When teachers' performance is measured by the passes obtained by pupils from a question booklet which relies heavily on recall and interpretation of evidence, then the teaching approach will place an emphasis on teaching 'facts' and strategies for the resolution of these questions. Also, pressure from assessment procedures can make the experience of education a negative one for the pupils (Pollard and Triggs, 1997). The existing system of measuring successful completion of a piece of work through recall of facts should change to encourage critical thinking skills and instead, make greater use of formative and peer assessment to complement the summative assessment currently employed.

To summarise, the research which I have carried out recommends that a policy which specifically promotes greater inclusivity be employed. This should reflect the need for continuity through the different stages of education with gender monitoring to highlight issues of inequity. A more inclusive curriculum, which gives rise to more interdisciplinary activities, a syllabus which is not over-loaded or prescriptive with appropriate attainment targets; encouraging more discussion, project work and investigation as well as more challenging activities in the classroom, could help to bring about greater inclusion.

The research found that pupils enjoyed putting forward their own ideas in the example of the project on water. They discussed the issues and implications in a critical manner and in doing so touched on the politics involved. They were then motivated to look for solutions and worked creatively on projects to suggest ways of resolving the issues. By creating their own success criteria, they were more engaged in the assessment process through deciding on the merits of each others' projects and whether

they satisfied the learning outcomes which pupils had set out. Learning more about a topic in this way, gave the pupils a greater sense of involvement in their own learning. It also helped to connect pupils' own experiences with wider national and global issues, akin to the science, technology and society (STS) approach which promotes studying science in its social contexts (Solomon, 1993; Aikenhead, 1994).

Through this approach, science is opened up to criticism in the same way that literature or art is in other areas and an exploration of how science is used in society, for better or worse, is one which connects with Harding's notion of a "science criticism" (Harding, 2006, p.62). Analysing science in its different contexts might improve the learning experience in science classrooms through opening up science to scrutiny and identifying both its benefits and its disadvantages.

For the curriculum developers, policy makers and practitioners, all involved in creating and shaping a new science syllabus, this research points to the need for the aims of science education to emphasise and question gender biases in science and draw this into the discussion with pupils to make practice more effective and inclusive.

### **An Inclusive Approach to Teaching**

A recommendation from my research is that teachers should consider the findings offered by this research in changing their approach to teaching science. These stress the importance of 'how' to teach as much as 'what' to teach and sharing good practice, which offers the chance for networking with other practitioners.

Teaching a more inclusive science has been one of the main aims of the research which I have carried out and a major finding from this data highlighted that the ways in which the subject is taught is crucial to pupils' enjoyment, understanding and decision to continue with the subject. The results from the research then have implications for teachers, teacher trainers, head teachers, heads of PGCE courses and potential teachers, those who are currently students on post-graduate teacher training courses.

Science classes can be more inclusive by making teachers aware of:

- the few numbers of girls in physics beyond S2 level
- how collaborative learning can improve the learning experience
- different approaches to teaching
- how questioning the methods used can lead to better practice
- the importance of sharing good practice
- the way that pupil investigation increases motivation on the part of the learner.

Many respondents to the interviews indicated that if the teacher made the lesson interesting and engaging, then it was worth continuing in that field. Good quality teaching in the first few years of secondary education, which includes discussion to let pupils voice their opinions and consider those of others, is crucial to changing attitudes towards science classes.

The study showed that when the lesson starts with the pupils' experiences, it can move forward with a topic and explore the wider implications at a social level. In seeing how the curriculum would look from a feminist perspective in this case, pupils were also guided towards a consideration of the way the topic is seen from the perspectives of different people and the way gender plays a part in the subject matter.

The delivery of the lesson is as much a part of change as the content and employment of the approaches used in the humanities could help to make science lessons more inclusive. The use of discussion is essential: listening to the opinions of the pupils, questioning attitudes and opening up the debate so that pupils question each other and deconstruct issues through analysis of values and beliefs which are held. The role of the teacher is important in prompting and questioning to keep the discussion moving forward.

However, the current structure of science lessons renders this approach problematic for two reasons. Firstly, there is a tendency for teachers to set out the background to the topic, instruct pupils on carrying out an

experiment which then restricts discussion to a focus on the results found by experiment and the conclusions reached. In addition, facilitating discussion depends on the teacher and in science education; open discussion has not traditionally played a significant part of the science lesson. The need then is for practitioners to extend the questioning which is part of the scientific process to wider issues.

It also recommends that teachers take a more active role in encouraging pupils to question the curriculum and the concept of science in asking how a subject is seen from different perspectives, particularly those whose backgrounds make them more marginalised. In doing so, it incorporates an exploration of the concept of science and science education from different standpoints by the pupils and teacher.

Secondly, inviting discussion of the role of science in society can also result in pupils feeling that science has had a negative part to play in the construction of inequality in the world and that they do not want to be associated with it. Such difficulties do arise and the argument against this would be that more scientists are needed who have a greater awareness of potential problems and who can produce a better science and technologies (Harding, 1996). If school science is modified so that it is less inflexible and more open to criticism, then the development of a new science can move forward. Science classes have in the past avoided analysis of science in society but when pupils can voice their opinions in class on what science means to them, and how they see its role in society, they can become more engaged with the subject.

Science teaching has not traditionally involved a lot of discussion and teachers might avoid difficult conversations, particularly ones which criticise science. However, if the syllabus specifically noted that discussion on gender issues in science as well as the implications of science and technology for the world should be an inherent part of learning about science, then science education would be a richer experience for all. Discussions which involve uncomfortable issues and criticism of science can help to generate ideas for a better science and ways to improve how science is utilised in society.

The research outcomes from the project work which I have carried out have been shared with other members of the science department as well as teachers in humanities. Pupil investigation of a topic can increase motivation and sharpen critical thinking skills. When the learner has more autonomy in terms of the ways in which they learn, this involves decision making. This in turn offers the possibility of greater responsibility for learning and the pupil is more motivated to learn when the topic is one that they have to explore themselves.

The research found that when debate begins with the learner and moves towards how this relates to wider issues, the pupils saw how their situation was part of a larger issue, connecting their concerns and experiences to those of others. In the case of looking at energy, pupils thought about the different ways in which they used energy and how life would be without that energy to power the things they felt to be important. Through the debate, pupils began to see how their lives were part of a wider picture, as consumers of the earth's resources, with implications for politics and the environment. By breaking down a topic into smaller sections which the pupil can personally relate to, such as their experience of using energy or water, then introducing the broader field: how this commodity is resourced, what costs are involved and what the political and economic implications are, pupils can see how they relate to the bigger picture. This makes the learning experience a more meaningful one and this type of discussion encourages collaborative learning as the pupils learn how to listen and contest the opinions of others. Their own views are challenged and questioned by their peers and stereotypes and biases contested.

Teachers have a critical role to play in creating a more inclusive experience of science education for learners. With more time being made available for project work and discussion, more in-depth analysis of science from different perspectives at a local, national and global level, teachers can make lessons more challenging and relevant for their pupils.

## **Collaborative Learning through a More Inclusive Curriculum**

The third area of change which this research recommends lies in changing the science curriculum for the early years of secondary education. Currently, teachers follow the first and second year syllabus set out in the 5-14 National Guidelines. This document is the basis for teaching science to pupils aged 12-14 and teachers and schools have developed a system of worksheets and standard apparatus for learning around 14 different science topics through it.

Teachers and pupils felt that the way in which these were approached in practice led to predictable experiments where pupils followed a 'recipe book' type of process and where outcomes were known to pupils. For example, in the case of studying water, pupils were asked to find out if stirring or heating helped to speed up dissolving and past experience of putting sugar in tea was sufficient to predict results. Pupils indicated that much of the practical work they covered was boring and repetitive which they had already studied at primary level or knew from life experience. The curriculum then needs to be shortened to a smaller number of topics which are covered in greater depth. These need to include project work and discussion to bring out the social context of science (Solomon, 1993; Aikenhead, 1994).

The recommendation from this study therefore is that the content of the syllabus be reduced to allow more flexibility on the part of the teacher to explore topics from a social and global perspective. The human aspects of the strands of science studied, such as water, energy and other topics need to be emphasised. The importance then is to reduce the number of topics which teachers are required to cover but to spend more time on a subject area by covering it in more depth and analysing it from different perspectives, with particular emphasis on the gender issues associated with the topic.

A good starting point when beginning a topic is to look at the web pages of different charities who are concerned with this part of the science curriculum. They indicate some of the problems for people at a global level who face difficulties through lack of money and resources and through this it is possible to introduce some social aspects to the theme. In doing so, the

ethical considerations are identified and can be debated. This could then lead to a discussion of the processes which go on in the world, such as the way sources of energy are distributed and controlled, how science plays an important role in the structures of society and how it could be used to better the lives of many people on a worldwide basis.

It would now be useful to look at some of the typical areas studied in the first few years of secondary education and the way these can be looked at from a different perspective, that which is informed by feminist approaches to learning, which seek to redress the current gender imbalance. The topics are wide-ranging, broadly covering the earth's resources, and the openness gives pupils the autonomy to explore new areas of interest seen from their own perspectives.



Table 6.1

## An Illustrative Curriculum

Topic	Introductory questions and prompts	Discussions and debate	Project work/ presentations/ posters
Energy	<p>What do you use energy for?</p> <p>Where does the energy you use come from?</p> <p>Does the energy we use have any affect on others?</p> <p>What are the national and global implications of energy use?</p> <p>What is essential? What are the disadvantages of energy use?</p> <p>What is the role of women in poorer countries in obtaining energy, like fuel for cooking?</p>	<p>How would your life change if you did not have this energy to live?</p> <p>Does energy mean the same to you as it would to people in poorer countries?</p> <p>On other societies?</p> <p>What is the need for energy in other cultures and countries?</p> <p>Should everyone have a right to energy? What are the ethical issues?</p> <p>Types of energy, renewable and non-renewable types of energy. Energy options issues.</p>	<p>Prepare a PowerPoint presentation on an issue of why energy is important in our lives.</p> <p>Show how the energy we use relates to the wider world.</p> <p>Environmental implications of energy use.</p> <p>Distribution, pollution, availability of energy.</p>
Water	<p>Watch the MTV video diary of Jay-Z</p> <p>Where does the water you use come from?</p> <p>How do you use it?</p> <p>What does the charity Wateraid do?</p> <p>Is the way we use water sustainable?</p>	<p>It is predicted that water will be the biggest issue we have to face this century. (quote from the UN)</p> <p>Why is that? What can we do about this?</p> <p>How are the lives of women and girls in poorer countries affected by the water available?</p> <p>What is the connection between water and the education of girls in poorer countries?</p>	<p>Produce a short presentation on the world's water problems.</p> <p>Water for Life!</p> <p>Water is a major concern for the world.</p> <p>Why is this?</p>
The Environment	<p>How do you use the environment around you?</p> <p>What do you enjoy about the environment you live in?</p> <p>What are the effects of pollution on our society?</p>	<p>How are we damaging the environment?</p> <p>Do people in other countries treat their environment as we do? Are they better at looking after their natural resources?</p> <p>What is the role of women in sustaining the environment?</p> <p>What are the links with health?</p>	<p>Look at a major environmental issue. Is it sustainable?</p> <p>What would happen if it continues?</p>
Keeping Healthy	<p>How do you keep healthy?</p> <p>In what ways can you keep yourself and your family healthy?</p>	<p>What are the problems faced by people in other countries in keeping themselves healthy?</p> <p>How is the health of women especially important?</p>	<p>What are the main health issues for people in the world? What are the main health issues for people in Scotland?</p>

The above suggestions for an alternative approach to learning about science involve collaborative learning. These should lead to debate and pupils can carry out an investigation then present their findings to highlight the issues which they consider to be important.

As has been seen from an earlier chapter on addressing the third research question through devising a more inclusive curriculum, one of the outcomes was that of raising attainment in low achieving pupils. This type of approach where pupils share the exploration and discovery experience can lead to all pupils benefiting from the process. The less able pupil is able to contribute through participation and contributing to the project, strengthening self-esteem.

By beginning with the pupil and their life, then relating their personal experience to global issues of poverty, lack of resources and the role of women in other cultures and countries, the learning process is more meaningful. Making links between their lives and the topic creates opportunities for engagement with interested bodies, from science research institutions to charities involved in dealing with these particular issues, such as Wateraid or Oxfam.

The assessment of the presentation or project should be through pupil evaluation of projects. When pupils decide on the successful learning outcomes and discuss why they think that a particular outcome is important, they are taking responsibility for learning. In addition, pupils are learning across the curriculum and can make connections between their experiences and that of others. They can discuss issues from a personal level and empathise with others whom they recognise to be facing greater difficulties in life than they do. My experience of using peer evaluation was that pupils took the role seriously and responsibly, offering sensible and honest comments on why they felt that a particular project or presentation had achieved its learning outcomes, or in what ways their peers could improve on the project if not.

Another outcome from the research from which recommendations follow is that of questioning stereotypical assumptions about gender roles. A topic, such as keeping healthy, which generates questions of food, where it comes

from, how it is produced and what the involvement of supermarkets implies for food production and distribution are important issues to explore. The role of women in feeding families and food production in other countries and what this implies for their education and health are all crucial questions which brings in perspectives from women's lives.

### **A Curriculum for Excellence**

A new policy for Scottish education which is currently in the process of implementation, A Curriculum for Excellence (ACfE), offers the chance to create a more inclusive curriculum for pupils. Proposals for change suggest reducing the number of attainment outcomes, developing informed attitudes in science and streamlining the curriculum from pre-school until the end of secondary. As such, many of its proposals relate directly to the outcomes I have found from investigation of this field. However, it makes no mention of gender and the research I have carried out could make a vital contribution to enhancing the impact of this new policy by bringing the issue of gender to the forefront during this time of developing a new curriculum.

Nevertheless, ACfE offers the possibility of a changed approach towards teaching science and the research I have carried out is opportune in terms of the significant contribution it can make to the ongoing changes to the curriculum in Scotland. The teaching profession in Scotland is ready for change after years of following a prescriptive and restrictive curriculum.

A Curriculum for Excellence was published in 2004, following a national debate on education in Scotland. This laid down out the principles, values and purpose of the curriculum for 3-18 year olds. These proposals are currently (December 2008) at the stage of preparation and development and from 2009-10 all schools and centres in Scotland will be delivering the new curriculum.

The objectives of ACfE show the relevance of the research I have carried out and the way in which the recommendations arising from it are both important and timely in the development of a new approach to the science curriculum. The changes which ACfE advocates may lead to many of the

recommendations which have arisen from my research being implemented, resulting in good practice through effective learning and teaching.

ACfE marks a return to a more thematic approach to teaching and a move away from the current guidelines which have acted to constrain the efforts of teachers, making them into passive recipients, rather than change agents, through weighty syllabuses of discrete subjects and tightly controlled assessment procedures. ACfE attempts to “declutter” the curriculum by suggesting fewer topics with more scope for discussion, interpretation of a topic and the way this is relayed to pupils. It sets out a wider remit of what and how young people should learn and asks teachers to engage with pupils and help them to make informed decisions about a variety of issues, through more interdisciplinary work, having a reduced number of learning outcomes, giving greater autonomy in approach and by streamlining progression from pre-school to senior secondary school level to avoid repetition of lessons.

ACfE identifies the need to re-think traditional ways of delivering the curriculum and outlines some key features for the future in secondary education:

*“Greater scope for different approaches to curriculum design in S1 to S3 within clear parameters” and*

*“Curriculum includes planned opportunities for broader achievements, interdisciplinary activities and choices as well as learning across all curriculum areas”.*

(Curriculum for Excellence, 2006, p.20).

ACfE proposes greater flexibility across the curriculum for an exploration of key concepts through the adoption of a more cross-curricular approach, with the ultimate goal of increasing pupils’ understanding of the real world. Within science, ACfE has the goal of encouraging children to look at the wider picture and to develop a “secure understanding of the big ideas and concepts of science” (A Curriculum for Excellence, 2006, p.30). It encourages children to recognise the impact science makes on their lives

and that of others and the ways in which the environment and culture are affected. It is also suggested that children:

*“express opinions and make decisions on social, moral, ethical, economic and environmental issues informed by their knowledge and understanding of science”*  
(ACfE, 2008, p.1)

Although there are difficulties in trying to create a curriculum which is less prescriptive and restricting, whilst delivering a challenging syllabus which teaches the key concepts in science, ACfE demonstrates the importance of policy in directing positive change.

To some degree, the research I have carried out and the proposals from the Scottish Executive are in agreement in terms of curriculum reform and in the approaches used. However, ACfE makes no mention of gender in its proposed changes to education and in omitting this vital aspect it risks losing the opportunity to create more inclusive practices. More prominence given to gender concerns would help to maintain the focus on creating a more inclusive curriculum.

My research has shown that there is a need for greater gender monitoring to highlight the low representation of women in physics and the resulting figures need to be made explicit and question why trends continue. There needs to be more debate about why so few girls choose to study physics amongst policy-makers, leading to a fundamental shift in emphasis of the science curriculum.

ACfE does not explicitly recommend strategies for making science more inclusive or mention issues of gender bias and this should form part of its rationale, in order to redress this imbalance. Many of the recommendations which I have made through this research could be implemented through ACfE, which would profoundly change what and how we teach. A good policy is the basis for improving the curriculum and both my recommendations and ACfE proposals put forward the case for streamlining the curriculum, reducing its content and changing assessment procedures. In the classroom, both set out a change in approach through more discussion, interdisciplinary and project work and valuing the learner's contribution. As

such, both show ways forward in improving the learning experience for pupils and creating a more inclusive curriculum.

### **Recommendations for Methodology**

The unique contribution which this research makes to methodology lies in its use of groups of curriculum development teachers to create new exciting ways of teaching science and to talk about how they could implement the curriculum. All teachers are curriculum developers and if they work together, as I have done with colleagues, they can look for ways forward and create more imaginative ways, making the learning experience a richer one for pupils. I have found that to achieve a level of sophistication in curriculum development, there is a need for focus group and curriculum development teachers' discussions on ways of taking the syllabus forward.

In addition, the methods of interviewing pupils were also distinctive and to be recommended for further investigation involving young people. I interviewed pairs or small groups of pupils who were from different subject areas, such as one pupil who was studying physics whilst the other had opted for humanities. I also paired male and female pupils together and by involving pupils who had made different subject choice options, I felt that this offered a greater opportunity to debate issues and for comparison of pupils' experiences as learners in these subjects.

### **Recommendations for Further Research**

In the process of undertaking research into science and gender, other questions present themselves which, whilst related to the field, lie beyond the scope of a research thesis such as this, which is necessarily limited in scale. The further research questions which arise from this work involve a different approach and broadening the research base of investigation of gender and science education issues.

Firstly, the study has used a qualitative approach to the collection of data. Feminist praxis (Stanley, 1990) emphasises the need for exploration through

discussion of feelings and this research was primarily concerned with attitudes, an aspect which requires dialogue with those involved in science education, as teachers or pupils.

However, the starting point for carrying out the research came from quantitative data, the statistics which pointed to decreasing numbers of pupils opting for science subjects and the continually low representation of girls in the physical sciences. The quantitative monitoring of education systems by gender at all levels is of utmost importance for without the figures to demonstrate inequalities in the representation of women in science and technology; the extent of the problem is hidden.

Secondly, there is a need for more qualitative evaluation of an inclusive pedagogy which can inform teachers of strategies and approaches they could employ in the classroom. The new Curriculum for Excellence (2006) offers the chance to progress in some of the areas which are recommended for change but the gender issue should also be stressed. As such, further research could build upon the work I have carried out in exploring broader areas for change and development in science education which also have a focus on gender and inclusion.

A Curriculum for Excellence should be examined, when completed, to assess to what extent it is more inclusive. This would involve looking not only at the quantitative data but also at qualitative research into attitudes towards science education, as this research has done. Questions should be asked of it, such as: to what extent are the experiences of boys and girls included in the science curriculum, does the curriculum encourage teachers to employ a range of approaches in the classroom and is the science taught more socially relevant to the pupils.

Further cross-curricular work by practitioners with humanities teachers should be carried out to move the issue forward. If science and humanities teachers were to develop materials for use in their classrooms in a collaborative manner, the learning experience for the pupils would be one which had more meaning and where connections could be made between subjects.

Finally, a comparative study would be interesting if the issue of science education were examined from a feminist informed perspective in the context of different countries and cultures, thus drawing this research into a wider domain. Other cultures, from my experience of working in the Caribbean and the Pacific Islands, have different attitudes towards science, ranging from admiration and complete acceptance of its status and claims, to rejection of the theories it produces and it would be informative to discuss the benefits and disadvantages of science with people who have a different viewpoint to that expressed in Scotland.

## **Conclusion**

The research which I have carried out raises many issues concerned with the current situation of science teaching and learning. The respondents in this research identified the lower secondary school level as being crucial for engaging pupils in science since this is the stage where pupils make choices as to which subjects they will continue with at higher levels. They pointed to problems arising from an overcrowded syllabus, a focus on process, repetition of work and little time for creativity, reflection and discussion, all of which contribute to the exclusion of many pupils, but especially girls, from the physical science classes at post-16 level.

Changes in policy through a more flexible curriculum to promote inclusion are vital, as is gender monitoring and changes to assessment. Teachers represent the key to changes required for an alternative science class using a feminist informed approach and can encourage debate and an exploration of science in the world and the gender issues involved. A changed curriculum and emphasis on widening the scope of science lessons to include discussion could help to progress towards a more inclusive science education.

The research I have carried out and the recommendations which it has pointed to can help to inform a new curriculum which is in the process of development in Scotland (ACfE). The changes advocated by it are important as they relate to this study in terms of offering the possibility of an alternative approach to teaching and learning in schools and also show how good policy can drive curriculum change forward. Implementation of the



recommendations from my research could help to bring about greater inclusion in science education and many of these recommendations may be achieved through ACfE. This research is timely in being able to make a positive contribution to changing science education through the new curriculum and its recommendations serve to bring that process to fruition.

## **CHAPTER 7: REFLECTIONS**

The research which I have carried out is one which began its journey as a puzzle: where were the girls in the physical sciences classes I was teaching in secondary schools in different areas of the world? In each country, the physical science classes were dominated by boys. This observation was one which I found repeated throughout different contexts and cultures.

I started to look for explanations as to why there were so few women in this area. What were their experiences of science and what was it about science that led women to choose other subjects? As a female scientist, I felt that not only were women missing out on opportunities in this field, but also that the scientific venture was continuing without the enriching participation of many women.

This journey has been one of changing attitudes and perspectives. I have undergone a shift in my ideas as to why there continues to be a low representation of women in science. Initially I felt that the girls were failing to see the logic and beauty within the subject and concentrating instead on other subjects of lesser importance. I enjoyed being part of a class which was considered to be of high status and of greater difficulty than others.

Throughout secondary and university level education I did not feel discriminated against in any way because of my gender, nor did I question the science I was taught. Instead, I accepted that this is how it is: most girls just don't do the physical sciences. Then on a more optimistic level: surely more women will move into the scientific world as career expectations and society changes?

However, an interest in the perspectives of feminist writers who challenge the current paradigm of science led me to a consideration that perhaps women were right to self-exclude from the male dominated and orientated scientific establishment. Why indeed would they want to be a part of such a system when they were unwelcome in this field?

Nevertheless, the notion of women being absent from science and through it, technology and industry, was both perplexing and worrying. My role as a science teacher seemed to be contributing to maintaining this situation.

What could I do to change the situation and how could the science I was teaching be improved?

This would require a process of deconstruction and then reconstruction to create a gender-free curriculum. Could a different approach towards teaching science help to redress the gender imbalance? Would girls want to be part of such a class? In what way could I begin the process of creating an alternative science curriculum?

The answers, I felt, lay in looking at the range of ways in which pupils and teachers viewed science. It also seemed important to look at the humanities to see why some pupils would find these subjects attractive, since as other subjects in the curriculum have been developed and are seen by pupils as more appealing and relevant to their needs, so science has been rejected by many pupils.

Feminist writers are critical of the science which has emerged from the scientific establishment, shown to be biased and subject to cultural influences. Although questioning and challenging the conclusions drawn from science per se may be beyond the remit of teachers, we can still work to change and contest the way science education is relayed to pupils. Indeed, I would argue that part of the role of the teacher is to facilitate this ability in their pupils: to question and challenge the science which is relayed to them in the same way that they study and analyse arts subjects. Far from being a detached presentation of facts and scientific knowledge, the experience of science education should empower pupils to hold up what is given as scientific facts to scrutiny.

A feminist pedagogy involves the pupils questioning the “facts” given as part of the science curriculum and encouraging investigation by starting from pupils’ ideas for practical work and projects. Science presents itself as unchanging and beyond questioning and I have encouraged pupils to challenge this assumption.

My perspective as a feminist science teacher has been crucial to the research in giving the view of both an insider, as reflective practitioner, and outsider, as a feminist with the ability to carry out research and change practice. By moving away from the traditional role which science teachers have adopted,

that of instruction and information giving, towards that of debate and discussion, science education can progress from one of mere product and process to widening understandings of how scientific concerns affect all people in the world. In doing so, issues of gender inequality arise and can be highlighted.

When the debate begins with the experiences of the learner and these are related to the wider field, pupils can see how their experiences are part of a greater concern, connected with the experiences and preoccupations of others. In this way, the criticisms of science by pupils and teachers that it often concentrates on the particular, leaving out the “bigger picture”, are addressed, helping to open up the subject to show the inter-connectedness of the topic with social, political and gender issues.

Science should be relevant, socially related and accessible to make it more interesting where it is presented to pupils - in the classroom. By introducing the idea of placing science in its social context and using different teaching approaches from humanities to debate and discuss aspects of science, it is possible for pupils to become more engaged with the subject.

Perhaps the most important lesson to be learned from trying different ways of thinking about science was not just to change the approach in a few set classes but to bring in this element of reflection into all classes. Pupils are used to debate and discussion in humanities subjects where they draw on other perspectives and this needs to be part of learning in science.

I view this study as a starting point for continuing this alternative approach to science teaching. The challenge will be in progressing and developing the curriculum further, rather than a reversion to “the same old physics”. The test then is to carry this research forward and continue to implement gender fair practices. Teachers, policy makers and curriculum developers are key participants in changing the perceptions of science and reversing the decline of pupils entering this field. One of the major elements of their role is to ensure an inclusive curriculum. A good starting point would be to ask themselves and reflect on “whose science, whose knowledge and for whose benefit?”

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## **Appendix I: Pupil & Teacher Interview Questions with Information Sought**

The interview questions, showing the questions which were posed to teachers and pupils. The question posed depended on whether it was being directed towards the teacher or pupil. Science teachers and pupils were asked what they found interesting about science and humanities teachers and pupils what they found interesting about that area of study.

Examples of prompts are included to show how the conversation was guided towards a focus on the subject.

The type of information sought is also included to clarify what type of data I was interested in collecting.

Question	Prompt or probe	Information sought
1. What do you find interesting about the subject you teach/study?	Personal interest, relevance, favoured parts of the course	Why participants are attracted to the subject , what it offers to them personally
2. In what ways do you think this subject is useful to you/them?	What skills are learned, relevance to career choice, learning about phenomenon and ways of thinking	The way the respondent views the subject and how it ties in with their life views and ambitions
3. In what ways do science / humanities contribute to our lives?	Development of technology, debate, analysis, understanding of people/ phenomenon	General characteristics of subject, wider contribution to society
4. Why do you think some pupils are more attracted to science / humanities?	Reflecting on the make up of the classes, peer or parental pressure, liking for a particular subject	Presentation of the curriculum, gendered nature of curriculum
5. How could we make science / humanities more attractive for boys/girls?	Content, inclusion of topics of interest, relevance to all pupils, encouraging debate on the subject , presentation of subject	Changing the curriculum, inclusion of other areas of interest, different approaches, gender question, perceptions of the subject, breaking down dichotomies

## **Appendix II: Example of a Transcript of Pupil Interview**

### **Pupil Semi-structured Interviews**

Three female pupils: Female Science Pupil 1 (FSP1), Female Humanities Pupil 2 (FHP2) and Female Humanities Pupil 3 (FHP3). The researcher is denoted by L.

- L: What do you find interesting about the subjects you study? I know that you are all studying different subjects, but I wondered if you could think of the main subject. Do you do science?
- FSP1: Chemistry.
- L: So what do you find interesting about it?
- FSP1: I like the bit about building things up from atoms. It all makes sense. I like the logic of it. I like learning about atoms.
- FHP3: I am doing modern studies and I like the politics in it.
- L: Is that something you find interesting?
- FHP3: Yes. I like politics and I now keep up with the news and stuff.
- FHP2: I like art because you get to be creative and free. You don't have to do what others tell you. You can do what you want.
- L: And you don't get that in other subjects.
- FSP1: Yes, there is no right and wrong answer in art. There are opinions. You can have your own opinion.
- L: So there is no right and wrong. Just shades of things.
- FHP2: Yes, when you are like doing things, making things, it is up to you whether it is good or bad.
- L: So you are judging it. That brings it to you, you get to own it. So what ways do you think it is useful? What are the skills you get? What can you use it for?
- FHP2: Because I want to do art, there is a lot of project work; you get to learn in the way you study at university.
- L: So you are more independent? How does that contrast with other subjects?
- FHP2: Well, up until this year everything I was taught was spoon-fed. Now I am doing psychology through distance learning. You get one period a week and you have to make sure you do it yourself.
- L: So again, you are working hard on your own. So that is a useful skill for the future?
- FSP1: I think in things like music or modern languages, you have to find a lot of things out for yourself, but in maths or science you tend to get a lot more of being spoon-fed.
- L: Do you think there is any reason for that? Could there be another approach, another way of doing it?
- FSP1: I think that it works quite well, you have to be more independent in study skills in humanities.
- FHP2: I have a friend who is studying chemistry and she is doing it through getting the notes and working through it herself. The teacher is only there to help. And the first year was really difficult, lots of people failed, but the second year, they got into the swing of it and my friend did really well.

- L: Are they doing it with other subjects?  
 FHP2: Not with physics, only with chemistry.  
 FSP1: I think it works quite well when you have already had a grounding in that subject, but to start with it would be really hard.
- L: In what way do you think it is useful?  
 FHP3: In modern studies, we are doing project work and you have to do a dissertation. Doing your own research is always more interesting.
- L: In what ways do science / humanities contribute to our lives?  
 FSP1: Well, there is medicine and lots of things. Like when they explain how something works in physics and you say oh, is that how it works because I just thought that it worked and there is a reason for it happening like that.
- L: You take it for granted that it just works?  
 FSP1: Yes, it is like in chemistry, with the why water freezes and it makes ice and the whole density thing and you say, I see. It did not strike me as strange before but now it suddenly does.
- L: So when they explain it, then you get the whole package.  
 FHP2: I was also thinking about geography, it is about people and it helps you understand people.
- FSP1: And modern studies is really good because if you don't do modern studies and you go to vote and you don't know what you are voting for. It all gives you a better understanding of politics.
- L: Why do you think some pupils are more attracted to science or humanities than others?  
 FHP3: Some people are attracted to modern languages.  
 L: Did you find yourself drawn to one or another?  
 FSP1: I found some days I would feel that one would be easier than the other and other days not. You just did not have to think about it too much.
- FHP2: I like art and things, but then I like maths too. I like logical things. I like the statistics and probability parts of it.
- L: Why do you like that?  
 FHP2: I don't know. I like probability.  
 FSP1: That is what I liked about chemistry; it all made sense, there was a reason. But then in the advanced level, apparently they say that what you have learned doesn't actually happen. This is what happens. Actually, it is far more complex. In physics too.
- L: Is there a chance of creativity then in science?  
 FSP1: It is harder in science because it concentrates on rights and wrongs. Although when we were making esters, we got to choose the smell we made.
- L: What about gender balance in the classes, in modern studies for example?  
 FHP3: At higher level, there are a lot more girls in the modern studies classes, but it is a smaller class.  
 FSP1: In our science classes, it might have been more girls in the chemistry classes. In physics there are usually more boys.  
 FHP3: I think a lot of boys are more mathematically minded.



FHP2: But perhaps because people think that they should be there.  
 L: So it might be  
 FSP1: I think that many guys also prefer the straightforwardness of science. I don't mean it in the sense that, oh, you are dumb, you do science. It is less having to go out and find the answer. It is easier in a sense.  
 L: But you did physics? Did you enjoy it?  
 FHP3: No, not really, I don't know why I did not enjoy it. At first I really found it difficult. I thought that there was no way I could get through the course and then at the end it all came together. I remember that all the other girls as well found that.  
 L: Was that the teacher? Or the content, you know, what you were studying?  
 FHP3: A lot of people did not like the teacher.  
 L: Did that influence your  
 FHP3: I don't know. I can remember understanding how he put things across. No, I did understand the content. I don't think it has anything to do with science, as I liked biology, but I never took it at standard grade and I am doing it at crash higher now. I really liked physics at standard grade but didn't like it at higher level.  
 FSP1: In physics they seem to jump from topic to topic, whereas I think that in chemistry, there is some sort of logical progression, where you can refer from one topic to another and it all makes sense.  
 L: Was the content useful?  
 FSP1: Well, it did not stay in my head. It went pretty quickly.  
 FHP2: I remember we were out sailing and I was in this bit of water and I couldn't see around it and I was sitting there wondering how high up I would have to be to see where I was going and I was doing all these physics calculations and it was like.  
 L: So it does come in useful?  
 FHP2: Yes, I honestly have been using it.  
 L: It is ways of looking at the world.  
 FHP2: I have used equations in art as well. Like the thing I am doing with an arch.  
 K: I think physics comes in when you are thinking about music as well.  
 L: Does it? So it can feed into lots of different things. How can we make science / humanities more attractive to boys or girls?  
 FHP2: I don't think we had enough time to do the experiments in physics. We did do some experiments, but when you do actually get hands on experience, you remember and understand better. Like on a geography field trip to study the things we were studying. My friend didn't go and she didn't do as well in that part of the paper because she didn't actually see it. She wasn't actually there.  
 FSP1: I think it is about seeing the end result. I guess a lot of guys with arts don't like to study things that are not black and white. And not a lot of people there are men.

- FHP2: There is only one boy in my art class, although there are only five anyway. I think it is because they think that it is all feminine and drawing and the image that they have is of drawing flowers. But actually, what Stewart does is really good, it is like, design and he is designing an album cover. So it is completely not like that at all.
- FSP1: I have never actually thought of science as being a subject which was masculine or male, I would have thought that would be more design.
- L: I suppose that is art as well.
- FHP3: I am doing a study on women in politics in the States compared to the UK. I think there are more women in the States in politics and at higher levels than here.
- L: That is interesting. Are there more women in politics in the States?
- FHP3: I think that there are more in higher positions than here. It is something that I would like to work on in university.
- L: That is lovely, thank you very much.

### **Appendix III: Example of a Transcript from a Teacher Interview**

Teacher semi-structured interview: Male science teacher (MST7).

L: What I wanted to ask you was what do you find interesting about the subject you teach?

MST7: What science or physics?

L: Let's talk about physics in particular.

MST7: Well, it is what I have studied for about eight years. I originally did engineering; I didn't want to do pure physics. So I did engineering. That is the cornerstone of the UK because if you don't have engineers, don't have physicists, then there is very little that can happen. From electronics, everyone is now working with iPods and things like that. Scientists somewhere need to know how these things work. We have digital cameras and interactive whiteboards these things are to do with physics. If it wasn't for physicists then these things would not exist. They impact on everyone's life, especially the impact of mobile phones. They are all to do with physics and engineering. Cancer treatment therapy, these are all the things physicists do to make the world a better place.

L: What skills do the pupils get from physics?

MST7: Well, they get to understand how things operate and why things happen the way they happen. OK, they might not be able to create a mobile phone, but they can design simple circuits and this may enable them to have some understanding of how things work.

L: In what ways does science contribute to our lives?

MST7: It is everything, that we touch and breathe, you have physics, chemistry, biology and all these things put together is how things work and how do we make things better. In chemistry, they introduce drugs which hopefully can help us. In biology, they look at the body and can rectify things when they go wrong. Tell people how we reproduce, how animals reproduce. These are all important things that people should know.

L: Because it is stuff that is around us, in our everyday lives?

MST7: With animals, I know it is not physics, but with animals, the kids are really enthusiastic about these things, because they might not see these things, they might not get taken to the zoo, they might have a dog but they might not have these things in the house due to various reasons, but it is an opportunity to see these things and touch them.

L: So science classes can do that?

MST7: Yes, last week we had all sorts of things in. cockroaches, we did not have the gerbils because they have new babies. Eight of them, much to the amazement of the science teacher because she thought they were both males. And they weren't, clearly. Good for her reproduction talk.

L: So why do you think some pupils are more attracted to science or humanities than others, when they are making their subject choices? Some seem to be switched off science and others who are the opposite.

MST7: I think a problem that a lot of schools suffer from, especially secondary, is that primary do a magic job and then when they come to secondary, they take a lot of the privileges away from them. Like

in primary seven, they have a lot of responsibility such as being monitors whereas in secondary, they don't have any responsibility really. Also, you need to take on board what they have done at primary school and build on what they have learned and take that forward. I think that in second year, a lot of kids get turned off, full stop. One reason is that they are growing up, secondly, because they might be doing stuff which is not of interest to them. Thirdly, they might not be motivated, they might not enjoy science. They might not like the idea of doing science in third year.

L: Even if they have enjoyed it in first and second year or primary?

MST7: Well, in second year, they are growing up, they are not the wee ones anymore, their enthusiasm wanes a little bit, perhaps because they are now in second year. In first year they work on the Richi project (a project sponsored by a family to encourage science in the school). They are really enthusiastic about that. They make some models and you think, wow, I couldn't do that. Others hand you one sheet of paper, but if that is the best they can do, then you can't ask for anything more. Maybe if we had more project work and investigations, but there is so much in the curriculum now that the chances of doing these things are limited. Like to spend a week on a project or what ever, you can't do it. So that is a difficult one. In third year,

L: Do you think that the curriculum should be more flexible?

MST7: It is something that the kids enjoy. And I think to do with life skills, I think that it is more and more and that has to do with the success of the Arichis (project). The head and deputy head came down to look at the projects and my three classes got the top five prizes. Nothing to do with me, but I gave them encouragement and gave them incentive and ideas. Some of them came up with brand new ideas you would never even think of.

L: Brilliant, How long are they given to do it?

MST7: They are given a week in school then two weeks at home to do it. At the end of the day, if I get something in, then they have achieved something. Then it is brilliant. Second year kids when they come into physics say that physics is too hard and it is because someone has told them it is too hard, whether it be a brother, sister or parent, aunt uncle, it is perceived as being difficult, the most difficult of the three. Biology is seen as being the easier option. Maybe I am wrong in saying that but that is the impression I have got. Therefore they take biology. If you notice, biology has more pupils than physics or chemistry. They are lucky to get half the numbers than biology. Is it because you have the animals in first and second year? Do they think great, I don't know.

L: Can they relate to it more?

MST7: Very possibly. Also the fact that people see physics as being maths as well, that is a problem. How do you get out of that? There is some maths, but not a lot. If you can work the magic triangles, then cover one thing up and write the other two down in the way you see them, then substitute the numbers in after that. How is that difficult? Physics has knelt down to that a bit in terms of giving them data booklets which has all the equations in it. This year all grades will have a booklet with all the formulae in it. So the pupils say, so why

do I need to learn it? But they still need to know it because they need to know how to use it and what is each variable. They have relented a bit but a lot of people are saying that it has devalued the subject. Arguably it might be but I don't know.

L: Is it making it more popular?

MST7: I don't know how many people honestly know. That is coming into play. How much it is pushed in second year when they are making their options. This year we pushed, but you have chemistry and biology as options so therefore slant on things.

L: But the case of physics is much more positive. There are many more people choosing physics at standard grade than at GCSE grade in England and Wales.

MST7: Interesting, I did not know that. People say as well that there are male and female issues. That female physics teachers can increase the number of girls taking physics but we have had a female physics teacher who started at the same time as me and that didn't impact on the numbers in the subject. I would need to check the numbers. In my higher class I had one and now I have four.

L: Compared to how many boys?

MST7: There is a total of eighteen, so four to fourteen.

L: Which is quite a good ratio?

MST7: Well, I don't know what the ratio was before the higher class, so I don't know if the percentages are getting better. Another problem was, I spoke to some of the girls in my Standard grade class and asked them if they would be doing higher and they said, I can't because I want to do biology and chemistry and you can't take the three sciences. So because of timetabling issues, you can't take all three. Because they want more widespread subjects so that pupils have more choice later on. I think it is more difficult in the English system where they narrow it down to three subjects. Who knows what they want to do at that age? I didn't. I did engineering at uni and so it is a very hard choice at that stage.

L: So how can we make science more attractive to those who are not choosing it, in the case of physics, girls?

MST7: I don't know why girls don't take physics, it is like tech, it is seen as a boy's subject.

L: Is it a cultural thing then? Cultural norms?

MST7: Yes, it has been around for years and there are still physics teachers out there who say that girls shouldn't be doing physics.

L: So teachers themselves share part of the blame?

MST7: Yes, some of the older generation. Yes, when I was a teacher training, one of the girls went out to a school and because she was a female, she got a very hard time. It was actually said to her that she shouldn't be there. How antiquated is that? The person who said that was very old so

L: So when they retire, that might change?

MST7: That might change but it is a slow process. I can't fathom that out. I can't understand it because that is not the way I am but there are still men in their early sixties who say that women shouldn't be working. So how do you get around that?

L: Until they move out of the system.

MST7: It might mean that there are people out there, grandmas and grandpas who. It is a major problem because the numbers of scientists out there is getting less and less. There are some schools who are deciding to take science off the core subjects. In this school, you have to take one science at least. How on earth can you take science off the core in third and fourth year if we are running out of scientists?

L: But that brings in other issues of why are you educating people. Is it just for a workforce?

MST7: Honestly, I don't know the answer to that question. You can have a physics club and all that. You can try and encourage girls to get involved in physics. Strathclyde University invite girls in to talk about careers in engineering and try and attract them to courses there. They can't get them. And how do you get them? You need to give lots of incentives to people there. You need to get them out of there and into teaching but it is a very tall order. It is difficult to get science teachers. Engineering has lots of money going into it. Depends on what makes you happy.

#### **Appendix IV: Example of a Transcript from Focus Group I Interview**

Transcript of Interview with Focus group 1: Male science teacher, (MST14), female science teacher (FST12) and female humanities teacher (FHT8)

- L: What I thought would be interesting to do would be to get everyone together who I have interviewed and to look at the last question and all the things you brought up about how can we make science more attractive and move it on from there. So I thought it would be interesting to include someone from humanities because it was interesting to hear what kind of things you thought were important and why we get girls moving towards humanities more so than the sciences. We talked about the kind of things that they do that really appeal to all children. So that was the humanities input from it and looking again at the sciences and the striking thing about the figures is that the girls are way ahead of the boys, it is nothing to do with achievement. It seems more to do with culture, the way presents itself.
- MST14: As being difficult. I think it is a stereotype. I think it brings a higher calibre of pupil as well. It can do. It is perceived to. Not the difficulty, but I think that the stereotype of it being a male orientated and dominated type of subject makes them feel.
- L: That they are not welcome?
- MST14: They feel that it is not for them. As well, it is perceived as being very difficult. And yet, as you say, the girls who take physics tend to do very well.
- FST11: Where do they pick up the perception that it is difficult? That would be the next move. Is it the fact that they need other skills in order to access the physics? It really doesn't stand alone. So you are not just looking for abilities in physics, you are looking for problem solving and other abilities. It is that kind of perception that in order to be successful in physics you have to be multi-skilled and you have to master a whole lot of paths.
- MST14: Yes, but I don't think that marks any problem. That is what puts them off. I think it is the perception that it is a male orientated and dominated subject. I have heard a theory that the stereotype of physics being hard and male dominated comes from primary schools.
- L: Really? Now who would give them that idea?
- MST14: Yes, the percentage of female teachers in primary and the greater likelihood of any scientific background being in the biological sciences, rather than the physical sciences and so they have this influence from a very young age. It is one theory. It is an interesting slant on it. Whether it is true or not, I am not sure.
- L: But it seems to make sense.
- MST14: It does make sense, but I don't think it is entirely down to that, I think there are a number of factors. I think that might be one of them.

- FHT8: It would be interesting to know what is taught in primary in terms of the sciences. What is taught in biology could be more orientated towards project work than the physical sciences.
- FST11: I think that when we are asked for help from the primaries, they are asking for help with the physical sciences. The implication from asking for assistance would be that they are happy with the biological sciences. If you could go down the line of putting more science teachers down into primary, and giving them training, then you I think that is what we had a try in doing. It is again a financial thing holding us back because we are willing to do it, to take science down to them and we can provide appropriate training. But I think that there probably is something in that, that it is a very female dominated environment. In the past, we have certainly been asked for support.
- FHT8: Also they don't have the facilities. They don't have a science lab, they don't have any equipment.
- FST11: Interestingly enough, we have helped our local primaries and the two units we have prepared for them have been physics.
- MST14: Forces and energy.
- FST11: And what we did in one of them was took the primary teachers out and trained them and put them back in, so there was none of this concept of physics being hard. I must say that I was stunned at the levels achieved. Having shown them the direction and what we wanted and what the materials are, it was stunning. So there was a way forward there. It tends to be close links, close liaison with primary and secondary. It is what we are doing to change the perception of physics.
- FHT8: I have just being doing some primary liaison and what struck me was how little actual science they were doing. There was a fashion show, a puppet show, a litter pick and a website and there was nothing there on what could have been useful science too. It was very much focused on humanities. You know, is this the right way forward, isn't it? How do we present our case for what is needed in the future?
- FST11: I think that much of what we do is, I have to say, politically driven. The fact that Mr. Bush has stood up this week and said that the future of the world lies in technology. We are willing to do it but we don't necessarily have the budget to do it. So it is official and money and effort and policy will follow that and we have started with primary and secondary liaison to change the image of science.
- MST14: But it is not a fair system at all. It is a staffing issue as much as a budgeting issue. They can't afford to have you out of school. There was not the money to pay for it.
- L: They do have other specialists, like art or PE who go into primaries.
- FST11: One of the ones that we were hearing about was a visiting science teacher who decided to take it down to nursery level. They took it down to nursery. Now if you win hearts and minds there, you can move with that. But that again, requires



a budget, the vision and the ability to try that. But I think that there is a cultural aspect there and if you can get the nursery kids on board, if you can say that science is part of everyday life, technology, then you have it.

FHT8: In primary liaison, we tell pupils that when they get to secondary, this is a whole new area, because they have only just scratched it. The accent was on citizenship, it wasn't on physical science. Unlike languages, when the 5-14 programme came out, where teachers were asked if they had any prior knowledge of French or Spanish and if they did, they could get time out to produce coursework. I do recall the primary teachers I was with at the time being panic stricken at the thought of having to teach environmental studies. And the thought was at what level?

FST11: They are crying out for engineers at the moment. We are so worried that we are going to get left out of the technological race. If you look at third world countries that are coming on stream, they are producing huge numbers of people with maths and science, technology, whatever. Our children have steered away from that. They will not in the future be able to compete. It is frightening. Science is at the forefront of technology and that generates wealth.

FHT8: We have also lost the apprenticeship. ICI and BP used to have huge programmes involving day release to get more

FST11: I think that is coming back full circle. I think the attitude towards it is changing. The idea of getting 50% to university, you don't necessarily want to cram them all in there. We will need plumbers, electricians, and all the rest of it. You can have different kind of levels.

FHT8: I think a lot of it is how it is perceived. But without the basic science, you won't go forward. So much of it is not practical based. It is about how you want your society to grow and come up. But at the bottom end of the line, you need your economy and without workforces, who have basic sciences, you won't go forward.

L: But you need that debate in science as well. You need to make it more attractive by incorporating different teaching styles or whatever.

FHT8: I do think that there are too many people doing humanities and they end up going back to do a second degree in a more practical area. They can all write political speeches but there are only so many they can do. At the end of the day, whilst they can produce codes of conduct and research and all that, they are not actually driving the economy; in the same sense as your finance manager would be where your scientist would be. Your engineers and apprentices. Educationally, it is of no use. Having said that, I personally think it is a terrific subject. And it is fascinating and you can learn a lot as you go to the different countries, different cultures and how their economies are driven and learn from that. But you still have to be able to apply it.

- FST11: How are they winning, in that they can produce all these qualified people and we supposedly more advanced, don't seem to be able to do it? Is there a perception that you will get a job more easily? But then you don't have so many jobs for humanities either. So many come out with an MA or whatever,
- FHT8: Then they have to do a post grad.
- FST11: So why can they do it, when in education they don't have the resources either? How do they make a convincing argument?
- L: Maybe they don't have that cultural baggage that we have?
- FHT8: Take somewhere like China, which is steadily marching forwards. It is not that long ago that they were all living a feudal, peasant type culture and went through the communist transition to get where they are now, light-years away from under-development. I think they have looked over here and said 'they have all that. That is for me'. So they have something to aspire to. We didn't really have that. It was created by Western technologies.
- FST11: And yet, Scotland has an incredibly rich background. It has produced more Nobel prizes than any other country for its size. I hammer this to my classes that we do have this wonderful concept of development in science and technology. But it is totally withering on the vine. I have on the wall a large poster, it sits behind me as I teach. 'Where are they all now?' because we don't produce them. But as a cultural background, that they carry, yes, it is there. Yes, there are a few out there, but we need somehow or other, to go back to the fact that yes, we are really good at this.
- FHT8: But it is in a position now where it conspires to control the world. In a lot of ways, development has brought conceit. To the point where you say that the reputation is withering. We have to start producing a bit more.
- FST11: On the other hand, I watched a science programme last night and OK it was more archaeology, with biological sciences, but all the leading scientists were Scottish women. They were doing reconstruction and technology. They were marrying up science with history and proving the ten plagues of Egypt, but it was all women from Scotland. So I still think that it is there, but we seem to be battling against cultural perceptions. So I keep pushing women and science but the pupils still perceive physics as male.
- FHT8: There also is a way of thinking that children don't want to work very hard. 'So why should I?' and they have got a point. I do think that there is this I will do as little as I have to do to get through things and there is no way for aspirations.
- FST11: We did have to battle and struggle and so on. Now would you encourage your children to do that? To take the easier option?
- MST14: The hard road?
- FST11: I have produced one of each, but it may be that that is also what parents encourage. If they perceive it as being harder,

may encourage their children to get a nice wee job with a nice wee life. What is motivating for us may not be as motivating for the customer.

L: Going back to changing the image of physics, what about changing how it is presented and merging it with, for example the biological sciences to make something new.

MST14: There is a large overlap, especially in the medical physics topics. It is an area which would appeal to those who have an interest in physics but also in biology and it might soften the image slightly. It would also allow those who see biology and physics as being quite separate, poles apart, that yes, there are areas where they overlap. They could also do the two sciences without having to do chemistry.

FST11: There are all these kinds of courses at university now where they do that. They want the biology and the physics for courses on optics and lenses. Courses on optometry. I think it is telling them that because the way forward is going to be looking at a lot of health physics and technology and all the rest of it. And trying to keep this aging population healthy. There are always going to be jobs there. Isn't the National Health Service the biggest employer in Europe?

FHT8: There is quite a lot of bias in the workforce even if the girls get through. I think there are lots of issues.

## **Appendix V: Example of a Transcript of Case Studies Teacher Interview**

Transcript of an interview with the third case studies teacher (J) on changing science education. The interviewer is denoted as L.

- L: As you know, I am interested in looking at science education to make it more attractive to pupils and wanted to find out more about the work you do in encouraging more students to opt for science. First of all, what do you do and what are the aims of your work?
- J: I currently lecture in aeronautical engineering at the University of Manchester. A few years ago, I worked on a project called People into Engineering in primary and secondary schools, trying to deliver material to make students enthusiastic and think in a positive way about engineering. I was involved in organisation of widening participation.
- L: What type of students was this aimed at?
- J: The idea was of increasing the number of people into university, people with no background or with a disability, ones who were bright or ones needing encouragement. It was also to do with getting women into engineering and science.
- L: How did this initiative come about and what aims did it have?
- J: All universities have widening participation groups. The higher education initiative funding has to do with knowledge transfer, transferring objectives to industry. It is to do with training and skills. This was a two year project which aimed to bring engineering to the forefront, especially school development. We had a half day presentation to do with forces / materials in junior schools. It was to do with aerospace and drag. Pupils made paper aeroplanes in KS2. We had one day of design and building for year 10 and year 11 girls. They designed hovercrafts. There were between 80 and 100 pupils so we divided them into groups, gave them the brief and they went on to make a hovercraft. When the organisation disbanded, one person carried on with Saturday morning engineering clubs for 12 year olds. They had 10 weeks of practical engineering activities and visited round a company.
- L: Any follow up to this?
- J: We also went to careers evenings and another project was called F1 in schools. This was a design project for Formula 1. It had a big design element. Girls were interested in design and got involved. We also sponsored science festivals and the schools project on Jodrell Bank. There was also an exchange of aerospace students who went into industry while the apprentices in Rolls Royce and Airbus went into universities for a week. Most places found an improvement after the roles were reversed.
- L: I am especially interested in exploring the reasons behind the low representation of women in science, particularly physical science. Why do you think that many girls are turned off science and opt for other subjects instead?
- J: I think the thing about school science is that it has a history of not appealing to girls. They are more interested in medicine than physical science.
- L: Did you like physics at school?

- J: I left school at 16 with no qualifications and in my 30s decided to return to university. I decided to do an Access course in Oxford and wanted to do a humanities Access course. When I went, the humanities Access course was full, but there were spaces in the science Access course. I thought that if I did a few weeks in the science course, just to get in, then I could say that I didn't like it and ask to be transferred to the humanities Access course. When I started the science course, I found that all the teachers were brilliant. I was completely wowed by the physics teacher who was excellent so stayed in the sciences. I think that more people are returning to university to do engineering.
- L: Why do you think that at secondary level, there are few girls in physical science at advanced level?
- J: In the primary, children are interested in everything. By year 7 (age 11-12), they are still OK but by year 9 (age 13-14), they really need to make an input. The universities do summer schools but it is too late by then and they are dealing with people who are already interested. They need to get in before year 8 (age 12-13).  
The universities are interested in attracting people there. But secondary science teaching needs to be got at from a different angle. Getting children to work out mathematical solutions in class means that they don't make the link between this and working in some institution later where they will need to be creative.
- L: What can schools do to change this image?
- J: Schools need to get involved in out of school activities, such as design and technology. We did one project where we got pupils to design a model race car from balsa wood. They were made and tested in a wind tunnel. But these things require teachers who are committed and willing to work outside of school hours as the project doesn't fit into the national curriculum.  
I think that basically, we need to educate people how to learn. We need to get to a personal level. If we can get them to associate themselves with someone's life, like they do in history nowadays.
- L: A cross-curricular approach?
- J: I like to hear about the history of science, how it got to where it is, how people got to where they are. We need to bring the fun and the personal element back into science. They have taken out many of the exciting experiments for health and safety reasons.  
There seems to be an inherent dislike of the physical sciences. Perhaps it has something to do with genetics.  
If people realised how interesting the jobs were and how great the earning potential, once they had gone through the boring part of learning the basic rules, they would be more inclined to do engineering.  
A recent survey found that engineering was the second highest job in a list of job satisfaction.

## **Appendix VI: Example of a Transcript of a Curriculum Development Teacher Interview**

Transcript of a curriculum development teacher interview. K denotes curriculum development teacher 2 and L denotes researcher.

- L: What worked best?
- K: I think that from the pupils' point of view that it was a broad assignment that they were given.
- L: That was the water project?
- K: Yes, the water project, they liked being able to go off and do it themselves and they liked the fact that it was quite broad but within boundaries.
- L: So it gave them a lot of scope, although it was under one title?
- K: Yes. And quite a lot of them pooled different things into it, they had different ideas. So they like being more independent with it, they like to go and find it out for themselves.
- L: So how did it work, in what way did it work?
- K: Well it was planned in advance so that we would give them a broad question or a broad statement about water being the biggest problem in the 21<sup>st</sup> century. We discussed that and showed them a bit of information about water, a little movie and said to them that they were to present a Power point presentation and we set up success criteria so that they would know if they had been successful.
- L: and they came up with the criteria?
- K: yes, that was it. How will you know if you have done this? Was what I said to them. And they said well, we will have something and it will be interesting and varied and there will be pictures and there will be different interesting things in it and people will listen and all kinds of things like that so we wrote them up. And referred back to them at the end to see.
- L: Do you think that was important?
- K: I think it gives them a bit of scaffolding, because we gave them a broad statement and said this is what you have got to do. You will know that you have done it when you have got all these things down. They knew they had some thing to work around and it did give them a bit of scaffolding without restricting their creativity.
- L: So you think it was successful?
- K: I think it was really successful and I think it could have been more successful but we ran out of time. It was right at the end when we finished and we didn't have any other time to do it. And we went right up to the bone to the point where the bell had gone and we were still trying to sort things out and it was a shame because I really wanted to say well done to all of them. If we had had more time, that would have been great.
- L: So do you think work like this should be built into the curriculum?
- K: I do, I think we should do a lot more. I know that the curriculum for excellence is wanting us to do the whole curriculum like that and take it from there and I think it would work really well. The only problem is that it wouldn't fit into the summative assessment we have got. The end of topic tests and things. We couldn't continue doing the end of topic tests in the way we do them at the moment

- and build these kinds of things in as well. Because you wouldn't cover all the things in the topic tests as well.
- L: But that is part of the Curriculum for excellence as well?
- K: Yes, but I think that some schools will want to go with their end of topic tests as well. That is what they are used to. It is going to be a long time before they can do it less on a summative assessment. Maybe we look at colleges and universities and how there is no test at the end of some of the modules that people do for them, there is just an assignment which checks for understanding and there is a built in amount of work that they have to know. And it could be more like that. The assignment could be on any format, it could be Powerpoint or whatever, and they are assessed on their understanding of science in that way, without actually getting a grade, without numbers.
- L: So how could it affect students' choices for science subjects? Do you think that these pupils at S1 now with another year of science would find it more interesting if there were more projects like this included?
- K: You mean leaving the system like it is and slipping in more projects?
- L: Well, I don't know, perhaps it needs a complete overhaul?
- K: Well, I think you could perhaps make them a little more structured so that it forms part of the curriculum that they have to know, maybe there will be certain questions that they need to answer while doing it so they can have, you know, use their own creativity and bring in their own ideas. Maybe there are two or three questions that they need to answer as well as assessment so that they answer these questions which is what they need to know. Know what I mean? So there are ways around it. It takes a little bit of the creativity away from them but I think you could have both of them until the curriculum is sorted out. It would be down to the individual teachers and whether they want to or not. Some people are not comfortable with doing that. I have been thinking about it a lot. You know the national qualifications, the standard grades, access to year 1, year 2, they all follow very similar pathways and we use these summative assessments from first and second year to work out which level you are going to be on. But say everybody starts at the same point, in third year, in a class for chemistry and it is not until they are down the line a little bit whether they decide if they are going to be in Intermediate 1, 2, or access 3. then we wouldn't need to use any summative assessment in first and second year to work that out and you are not pigeon-holing them either. When they start in third year they would then be capable of saying look, I am better than access 3 or whatever.
- L: So the late developers.
- K: Yes, because it is very similar. Look at the same ideas of science but at different levels. It would be self-differentiating wouldn't it? What we are going to look at today, some of you will get this from it and others will get that from it and so on.
- L: That sounds so good because they get put into levels.
- K: They get pigeon-holed so young, at the age of 12, they are saying you are only capable of Access 3 or Int 1 and that is what the

Curriculum for Excellence is all about. You get them in your class and you find out that it is too late.

L: So hopefully it will be a bit smoother? And begin at the start.

K: Which could be full of investigative projects and use their problem solving skills, investigating skills. Because we all know that they have knowledge and understanding skills from primary school.

L: My concern as you know was about the numbers of girls opting out of science which is massive and increasing over the years. Do you think the projects that we did would be more appealing?

K: Yes, because it would be science in their way. We are all scientists, you are at home in your kitchen cooking and putting different ingredients in and working out how they all go together. We all do science on a daily basis and I think that we forget that and think that scientists wear plastic specs and wear white coats. And they forget that science can be glamorous as well. If it wasn't for science, we wouldn't have out make-up, our hair dye. We have lost the focus I think a little bit. That is why I wanted to work in science, I wanted to work for Estee Lauder and make lipstick. There is a lot of glamour in science as well and nobody focuses on that.

L: There are smelly labs and white lab coats and it is all a bit dour.

K: Yes, and I don't think the environment in this school helps because they are not modern. So it is not a place where you come to do fabulous, exciting, glamorous things. Hopefully, the new school will change that.

L: But the work itself for the girls in the class, because I saw that enthusiasm and getting all excited about doing the work and you see all of that and they were working in collaboration.

K: And also because they are doing it at their own level, being successful at the level they are working at, rather than having an imposed level from a teacher or whatever. They are doing something they feel good about and being successful, not just on a science level but on other levels as well, like presentation, ICT skills, cross-curricular work as well, where they could start a project in one subject and carry it through. So there is continuity.

L: That would be great as well.



## Appendix VII: Pupil Evaluation of the Water Project

## Water for Life!

1. Which part of the project did you like?
2. Do you think you learn more doing project work?
3. How could we make it better?
4. Would you like to do more project work?

## Appendix VIII: Categories of Responses from Interviews

<b>Outcomes / Participants</b>	<b>Wider views of science</b>	<b>Narrower views on science</b>	<b>Contribution from the Humanities</b>	<b>Making science education more inclusive</b>
<b>Pupils</b>	Useful in everyday life. Understanding how things work. Analysing skills. A decent job.	Not exactly creative. The same old physics. Here's the facts, learn it. Contradictions. Physics is hard. Sort of a boy's subject.	Doing your own research is always more interesting. You get to be more creative and free. There can be multiple answers.	It's about trying to make it more interesting. More fun experiments. It's the teachers who make it interesting.
<b>Teachers</b>	Physics is universal. A rationale for understanding the world. Making life better. Practical.	Reinforce their machoism. Discrete facts and disengagement. Breaking down the stereotype of physics is hard.	Language is at the base of every type of learning. Touch into your own emotions. Never right or wrong.	More project work and investigations. Making science more interesting.
<b>Focus Groups</b>				Marrying up science with history. Close liaison between primary and secondary. Soften the image. Breaking down the dichotomy of arts and sciences.
<b>Case Studies Teachers</b>				Made to feel special. Single sex physics classes. The need for creativity in science education.
<b>Curriculum Development Teachers</b>				Encourage children to express their opinions. Cross-curricular work.